Popular Astronomy

Vol. XLIX, No. 9 NOVEMBER, 1941 Whole No. 489

Neutrinos and Novae

By DEAN B. McLAUGHLIN

In the August number of POPULAR ASTRONOMY, Professor George Gamow[1] discusses the neutrino emission theory of the origin of novae and supernovae, and refers to the eventual explosion of the sun as a common nova, since he regards it as insufficiently massive to produce a supernova. The present writer is not able to discuss the theory of neutrino emission *per se,* but he believes that there are fatal objections to its specific application to the common novae, as distinguished from supernovae. The basis of these objections will be found in the June number of POPULAR ASTRONOMY[2] to which the reader is referred for details. A note on objections to the neutrino mechanism as the cause of common novae was published in the *Physical Review.*[3]

To make the present paper self-contained, we give a summary of the arguments. The starting point is the observed fact that the pre-nova and post-nova photographic luminosities of stars are the same. Such equality indicates that one of three things is true. (1) The star has the same radius, surface temperature, and spectral energy distribution both before and after the outburst. In this case it is immaterial whether the black-body radiation laws are obeyed or not. (2) The star radiates as a black body, and the change of temperature and radius just compensate one another in the photographic wave-lengths. (3) The radius and temperature have changed, but the energy distribution has been so modified (in an unknown manner) that no calculation of temperature or radius is valid,—nevertheless the *photographic* luminosity is the same.

Case (1) is the simplest. The end product is like the original star, and there is no difficulty with any fact of observation, not even excepting the faint record of the spectrum of Nova Aquilae 1918 some years before its outburst. All the relevant data have been fully discussed in the paper already referred to.[2] The existence of repeating novae *proves the fact* of return to the pre-explosion condition in at least three cases. Nobody who has examined the spectra of repeating novae (at both maximum and minimum) can deny their close similarity to those of typical novae. The U Geminorum stars have less violent outbursts at intervals of a few months, their spectra show marked similarities to those of novae, and there is no indication of their "running down."

---

[1] POPULAR ASTRONOMY, **49**, 360, 1941; see also *Phys. Rev.*, **59**, 539, 1941.
[2] POPULAR ASTRONOMY, **49**, 292, 1941.
[3] *Phy. Rev.*, **60**, 62, 1941.

Case (2) is the hypothesis of collapse, as usually set forth. In the earlier paper the writer has shown that it is untenable for common novae, unless we admit a large change of *real* or bolometric luminosity from pre- to post-nova stage. Thus, if the original star were of solar type and the end product a Wolf-Rayet-like star, such as is observed in every old nova that has been examined, the equality of photographic luminosities before and after outburst implies that the post-nova star is permanently more than three magnitudes brighter in total radiation than the original. The collapsed star of white-dwarf type should be expected to deviate from the mass-luminosity relation in the same direction as other white-dwarfs. The companion of Sirius is too faint for its mass. We have just seen that the collapse hypothesis requires the post-nova star to be brighter than the pre-nova object (which may be supposed to agree with the mass-luminosity relation). Thus the required change is in the direction just opposite to the deviation of an accurately measured white-dwarf. Case (2) thus involves grave difficulties; it is indeed self-contradictory.

Case (3) is one which the writer is unable to view as anything other than a refuge of those who cannot face facts. The equality of photographic brightness before and after outburst, with change of all the star's physical characteristics, might happen once by accident. But such equality is the rule, and if case (3) applies, then very peculiar and special conditions of radiation are implied. In particular, this hypothesis demands enormous irregularities of energy distribution, but it further requires that they all be outside the observable region of stellar spectra, since the observed energy distribution in the spectra of old novae is smooth and continuous. Indeed, as the writer has mentioned elsewhere,[3] one must almost believe in a star having the diabolical intent to deceive the observer.

From these arguments it followed that case (1) is strongly favored by the existing evidence; it is the only one that can be believed without actually disregarding certain valid observations. That being the case, we must conclude that potential novae are a small and special group of stars with distinct and recognizable peculiarities of spectrum. It has been pointed out that they are neither main sequence stars nor true white-dwarfs; rather they are very hot sub-dwarfs. The average absolute magnitudes of novae at maximum are not above -7, the average range is 11 magnitudes, so that the absolute magnitude of a typical potential nova is $+4$ visual. Because of its high temperature, the bolometric absolute magnitude is $+1$ or 0; this makes it quite dwarfish for a Wolf-Rayet star.

Professor Gamow apparently assumes that the high frequency of occurrence of common novae implies that any star whatever is eligible to become one sooner or later. The writer is unable to agree with this assumption. Three novae have been observed to repeat,—*why can't others*? The negative fact that others have not been seen to do so may

simply imply that we have not yet observed them long enough! The preceding discussion limits nova activity to a small and distinct class of stars. If we grant that the members of that class can have repeated outbursts, then we have no difficulty in seeing why there can be so many novae without every star being eligible.

Although the preceding paragraph may appear to be pure conjecture, there is some additional ground for the belief that all novae may repeat. Several years ago the writer was toying with the idea and found that a plot of the range of magnitude against the logarithm of the interval between outbursts of U Geminorum stars and repeating novae gave a rather definite straight line. While he was trying to decide whether or not it was wise to publish anything so novel, he was saved the necessity of that risk by the publication of the same indentical relation by two other authors![4] The relation given by them is

$$A = 0.80 + 1.667 \log P,$$

where A is the range of variation in magnitudes and P is the interval between outbursts, expressed in days. Introducing the average range of a common nova, 11 magnitudes, we find that the interval of repetition would be 3,500 years. No wonder we know of so few cases of repetition! Of course this calculation involves a large extrapolation, and we must not claim to have established the truth of repetition by all novae, but the evidence appears to favor that hypothesis much more than the supposition that any star can become a common nova. This is an interesting subject for speculation, in which complete certainty is not attainable. The conclusions reached are, as Mark Twain remarked, "interesting if true, and interesting anyway."

If the writer has not misunderstood Professor Gamow's hypothesis, the sun is supposed to pass directly from a position on the main sequence into the nova condition. He places the date of the explosion some billions of years hence, when the sub-atomic "fuel" has become exhausted. At that time the sun would have a luminosity about one hundred times its present value. Interestingly enough, this is close to the probable bolometric luminosity of present-day novae at minimum, but according to the foregoing discussion they are not main sequence stars. If the sun is to become a nova, it appears as if it should first develop into a hot subdwarf by passing diagonally across the main sequence. Whether it would perform this transformation smoothly or suddenly we are not ready to say, but if the change were sudden it would probably release an amount of energy comparable with that of a supernova outburst rather than that of a common nova.

Supposing now that the sun has somehow attained the hot subdwarf stage, after it has remained there for some time it has a common nova outburst,—then what? After the flare-up has passed, its photographic luminosity is unchanged; there is no evidence whatever that any col-

[4] Kukarkin and Parenago, "Stellar Variability" (in Russian), p. 222, 1937.

lapse has occurred, for it is still a hot subdwarf. We may perhaps conjecture that there was a slight collapse which released the energy of the common nova outbreak. Before it could become a really super-dense body it would have to have another slight collapse, and then another; in other words it would be a repeating nova. The complete collapse in one fell swoop would release energy a thousand times in excess of that observed in a common nova explosion.[5] The hypothesis of neutrino emission has little to recommend it as a means of accounting for common novae unless it permits a star to collapse gradually by small stages, with repeated outbursts. Unless the writer misinterprets the hypothesis, such gradual collapse is not allowed.

The objections which have been raised against the origin of common novae as a result of loss of neutrinos cannot apply to the supernovae, in the present state of our knowledge. We know nothing about their pre-outburst condition, except that they are less luminous than supergiant stars. In other words, it is possible to believe that almost any star in our own or any other galaxy is a potential super-nova, but not a potential common nova. Indeed, we might omit "almost" in the above sentence, since the relatively small number of supergiants would have to wait long, on the average, before one of their number was chosen. Thus there is no possibility of refuting the contention that the sun will end its stellar life by collapsing from the main sequence to the white-dwarf state at one jump, when the sub-atomic "fuel" has given out. But such a collapse would certainly produce a supernova. There appears to be no reason to object to the application of the neutrino emission mechanism in this case.

This denial of the neutrino mechanism for one type of nova and its admission for another may appear quite arbitrary to those who are familiar with only their light curves. But there are several reasons for regarding the supernovae and the common ones as two different phenomena. The superficial resemblance of the light curves must not be allowed to deceive us into assuming that they are so alike in other respects.

In the first place, there is a great discontinuity in the luminosities. Common novae cluster about —6 or —7 absolute magnitude. The supernovae, on the other hand, show only a small dispersion about —14. So many of the latter have been found that we have a right to expect that objects of intermediate brightness would have been found if they existed. But no definite case of that type has been discovered. Unless we very greatly underestimate discovery effects, the hiatus as a real one.

Secondly, the spectra of the two classes differ greatly, though we should make the reservation that missing links may be detected in the future. Indeed, the possibility of such connection is suggested by the spectra of the relatively few supernovae of "Group II," which appear

[5] Milne, *Observatory*, **54**, 144, 1931.

similar to those of common novae, but show unprecedented velocities (or band widths). Their luminosities, though lower than those of "Group I", are far above those of any common novae. The spectra of "Group I" apparently have no features in common with those of ordinary novae, save for probable bright lines of [O I].[6] No spectra of an intermediate type are known.

Thirdly, the writer[7] has shown that common novae exhibit a distinct relation between the velocities of their absorption spectra (or widths of their emission bands) and their rates of decline of light. The higher the velocity the faster the light fades. But the supernovae, with light curves which decline more slowly than those of the most rapid of the common variety, show band widths which indicate much higher velocities. The discrepancy points to a discontinuity between the two classes, unless the rate of fading, expressed as a function of the velocity, reverses for higher speeds.

These considerations furnish good reasons for entertaining the belief that supernovae and common novae are produced in two different ways. If the hypothesis of neutrino emission applies at all, it would seem more in accordance with the known facts to limit it to supernovae. Nothing so drastic is needed to account for the relatively feeble eruptions of common novae. If the neutrino hypothesis is invoked to explain them, it must also explain why so little energy is released. The evidence of a return to the pre-nova state is sufficiently convincing to rule out any form of the hypothesis of a single great collapse in a common nova. But even in its application to the supernovae, the writer does not feel ready to join the ranks of the "true believers" of the neutrino mechanism. He remains for the present a follower of Mark Twain. The neutrino has not yet been "caught," indeed its properties seem to be such that it will be peculiarly difficult to catch, and even its existence is to be regarded as theoretical. With the example of phlogiston, caloric, and the more recently defunct ether before us, we should hesitate a little before claiming to have really established that stars explode because neutrinos escape from their interiors.

Perhaps it will be the ultimate fate of the sun and of every star to become some kind of a nova at the end of its career, though the writer is one of those who would hold out for the belief that not all stars must die a violent death. Let us put down as one possible course a gradual and quiet decline into obscurity, even though current theories of stellar evolution leave little or no room for this sort of end. What are the other alternatives? Several billion years hence, whether because of the escape of neutrinos from its interior or for some other reason connected with the exhaustion of subatomic "fuel," the sun may suffer an internal readjustment because its supply of energy simply is not sufficient to keep

[6] Minkowski, *Pub. A.S.P.* **53**, 224, 1941. See also Hubble, *Ibid.*, 152.
[7] *Aph. J.*, **91**, 369, 1940.

it inflated. This readjustment will involve the release of gravitational potential energy sufficient to produce an explosion of nova-like magnitude. There seem to be two possibilities in this direction. First, if the sun has developed in some way into a hot subdwarf star, it may explode not once but many times, with a slight readjustment each time, until it eventually reaches the condition of a super-dense star. Any one collapse may produce a change so slight as to be less than errors of magnitude observations, but the cumulative effect of hundreds of these changes would be great. The alternative course would be followed if the sun was still a member of the main sequence. In that case we may expect it to end its life as a bright star in one stupendous collapse and the accompanying burst of glory, whose end product will be an extreme type of white dwarf. The distinction between these two alternative courses cannot be assigned a physical reason at this time (at least not by the writer) ; it is simply what the observations suggest. But I am reminded once more of Mark Twain.

THE OBSERVATORY, UNIVERSITY OF MICHIGAN, AUGUST 20, 1941.

Planets and Sunspots

By H. HELM CLAYTON

About thirty years ago Professor Arthur Schuster became interested in the question whether sunspots owed their origin entirely to internal forces in the sun or whether they were in part due to both external and internal forces.

In regard to supposed planetary influence he said, "The tidal effect of the planets on the sun's outer shell, which has been suggested by several writers, is generally believed to be too small to be effective, but gravitational effects may be much increased if there is a layer surrounding the sun in which gravitation is to some extent counterbalanced by radiation pressure."*

He then proceeds to make a calculation, in the light of the information then existing, in regard to the pressure of light, and concludes that tidal action of the planets on the sun is not impossible. He adds, "We are not, however, dependent on radiation pressure for a plausible explanation of a planetary action on the outer shell of the solar globe, which may be purely electrostatic."

He made calculations based on that assumption, and showed that, given an atmosphere positively electrified, it would be possible for the outer atmosphere of the sun to be in equilibrium in which small tidal movements might manifest themselves.

Interest in these speculations led me to inquire statistically whether

*A. Schuster: "The Influence of the Planets on the Formation of Sunspots," *Proc. Roy. Soc.*, London, Vol. 85, 1911, pp. 309-323.

more sunspots would be found when the planets were in different parts of their orbits, assuming that the tidal forces would be greatest when in perihelion. In making the calculations the perihelion of each planet was taken as the point of beginning and the monthly sunspot relative numbers prepared at Zurich were used.

The results of the computations are plotted in Figure 1. This figure with the tabular matter from which it was constructed appeared in

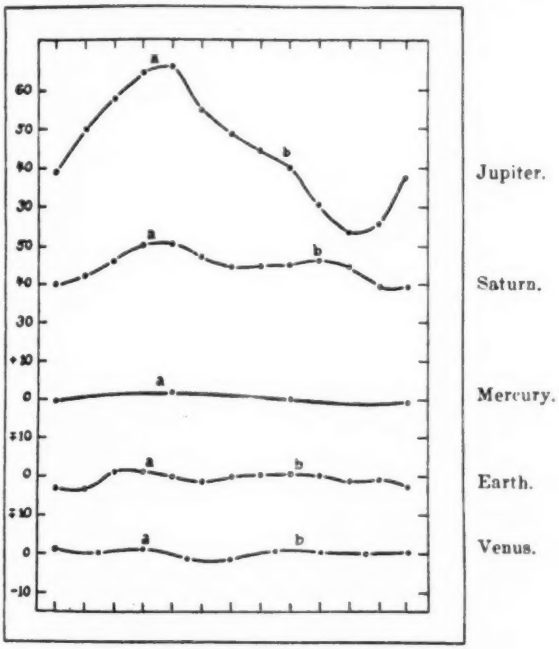


FIGURE 1
Sunspots during Sidereal Periods of Planets.

"Earth and Sun" by Ellsworth Huntington, p. 228, *Yale Press,* New Haven, 1923. For Jupiter and Saturn the results were based on all the sunspot data, 1749-1913, but for the small planets the observations from 1856-1913 only were used.

The diagram indicates a double maximum for each planet marked *a* and *b* during a sidereal revolution. The oscillations, except those for Jupiter, are not large but the positions of the maxima are surprisingly similar.

Dr. L. A. Bauer was impressed with the fact that numerous electrical and magnetic phenomena apparently associated with solar changes show a double annual period, and sought to connect these changes with the

small double oscillation in sunspots shown during the earth's annual revolution around the sun which he called the "Earth Effect."*

His comparison is shown in Figure 2. This diagram brings out clearly the double annual period in electrical and magnetic phenomena which are somehow related to solar changes.

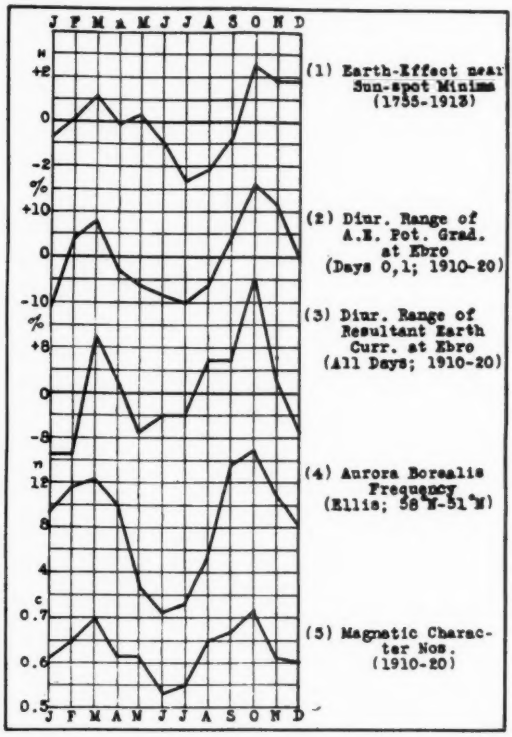


FIGURE 2

Annual Periodicity of "Earth Effect" on Sun-spottedness, Diurnal Range of Atmospheric Potential-Gradient at Ebro Observatory, Aurora Borealis Freqüency for Region 58° —51° North, and of Terrestrial Magnetic Activity.

In POPULAR ASTRONOMY for December, 1940, Vol. 48, No. 10, Professor William A. Luby suggests the precessional pull of the planets on an oblate sun as a cause of sunspots.

After speaking of the small values of tidal pulls of the planets, he

*Louis A. Bauer: "Correlations between Solar Activity and Atmospheric Electricity," *Terr. Mag. and At. Elec.*, pp. 23-28 and 161-186, March and December, 1924.

says, "However, precessional action of a planet on the sun is enormously greater than is tidal action and its disturbance of solar equilibrium is correspondingly large."

He cites as an example of precessional pull the movement of the waters in the Gulf Stream following high and low declinations of the moon which were investigated by Admiral J. E. Pillsbury while attached to the United States Coast and Geodetic Survey and published in the *Report of the Survey* for 1893.

He further cites the widely accepted theory that sunspots are the ends of horizontal whirls or vortex cylinders on the sun which might easily result from precessional pull on the sun's surface.

This interesting suggestion moved me to examine again the diagram shown in Figure 1. For the three planets Venus, Earth, and Saturn, which show the double sunspot effect most markedly, the number of degrees of longitude from perihelion to the position of maximum departure of the planet from the plane of the sun's equator is for each planet as follows:

	S	N
Venus	32°	212°
Earth	62	242
Saturn	55	235

These points do not differ greatly from the positions of the maxima *a* and *b* shown in Figure 1.

As a further test the sunspot numbers were computed anew for each month of the sidereal periods of Venus and the Earth beginning with the south position of maximum departure of the planet from the plane of the sun's equator. In the case of Venus an interval of 104 years was used, 1837-1940. In the case of the Earth an even 100 years was used, 1838-1937.

The results are plotted in Figure 3 on a larger vertical scale than in Figure 1, so that the oscillations appear larger. The scale values are departures from the mean and amount to about one sunspot in the average of 100 years. In the case of the earth they do not differ appreciably from the values found by Professor Luby.*

The middle curve in Figure 3 shows a plot of mean sunspot areas for each month for the interval 1874-1913 obtained by Henryk Arctowski.† The continuous curves in this diagram are plots of the harmonic values of a double period (A_2) computed from the observed values in each case. The observed values are shown by the broken lines. The small squares show the positions of maximum declination of the planet from the plane of the sun's equator. It is seen that both for the Earth and for Venus the maximum of sunspots in a sidereal revolution is surprisingly close to that called for by Professor Luby's theory.

In the case of Jupiter and Saturn the interval covered by sunspot

*Popular Astronomy, Vol. XLVIII, p. 527, December, 1940.

†*Memorie della Societe degli Spettroscopisti Italiani*, Vol. V, 1916, pp. 98-99.

observations is too short to change materially the positions of the maxima *a* and *b* from the positions shown in Figure 1 by adding a few additional years.

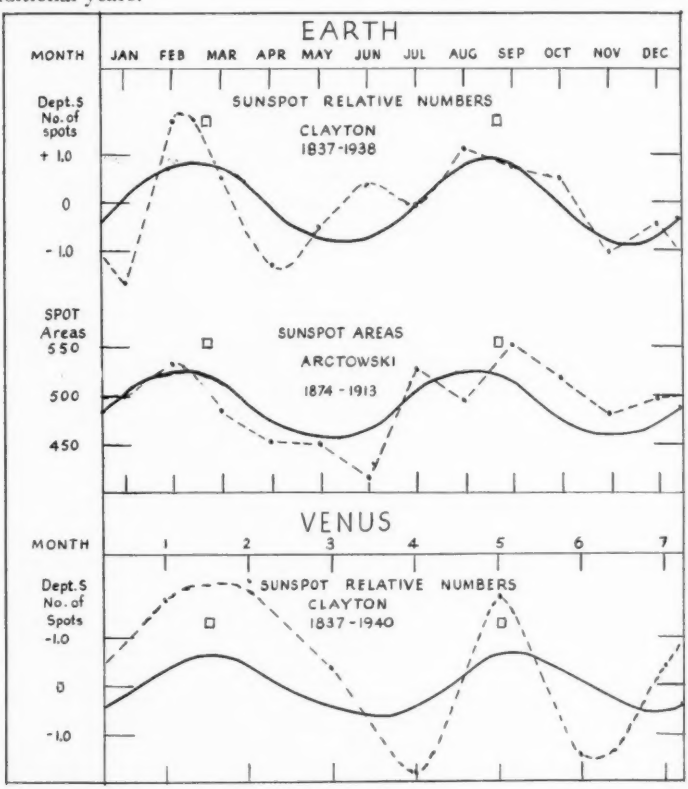


FIGURE 3

Variations in the number and area of sunspots during sidereal revolutions of the Earth and Venus. Small squares show positions when exerting greatest precessional pulls on sun.

Notwithstanding the close coincidence of the maxima of sunspots in the periods of the Earth and Venus with their greatest departures from the plane of the solar equator during the period of revolution around the sun, conservative astronomers will probably demand more exact computations of the physical forces involved in producing horizontal vortex cylinders on the surface of the sun before accepting the precessional theory, but it is hoped some mathematical physicist will be spurred to obtain further evidence for or against this theory of planetary action.

Observation of the Brightness of Comets

By N. T. BOBROVNIKOFF

One of the most striking facts in the history of astronomy is the tremendous amount of attention devoted to comets until very recent times. The comet of 1577 may be considered as the beginning of the scientific study of comets, since Tycho Brahe proved by the absence of its parallax that it must be beyond the "lunar sphere." An admittedly incomplete list of tracts and treatises on this comet contains 111 separate items.[1] Another landmark in the history of astronomy, the comet of of 1680, discussed by Newton in his *Principia,* produced 141 treatises,[2] some of them in considerable length. Coming to modern times, we have investigations ranging from the monumental work of G. P. Bond[3] on Donati's Comet of 1858, collating all physical observations of that comet, to short notices devoted to some particular phenomena observed in connection with this or that comet. Only in the last few decades when the attention of astronomers became concentrated on the larger problems of the structure of the universe and stellar physics has this stream of observational information about comets shown signs of running dry.

It is evident that much valuable material concerning physical properties of comets is buried in the files of astronomical periodicals and treatises or even in photographs and spectrograms of comets obtained at various observatories but never studied. Each bright comet, however, shows a baffling succession of phenomena, none of which can be rejected only because the observation seems too improbable. No spectrograph or photographic plate was available when comet 1861 II was in sight, bright enough to cause distinct, well-defined shadows. None of us may ever see a comet like that. Therefore, the remarkably complete observations of Julius Schmidt[4] of this comet and others will always retain their importance, no matter how our ideas about comets change.

We may say that there is no such thing as obsolete data so far as comets are concerned. Of course there are plenty of poor observations, and the investigator's job is to separate the wheat from the chaff. Among the fifty-one comets the tails of which had been investigated by Bredichin,[5] twenty-eight appeared before 1861, the year of his first paper on comets. The first of Bredichin's comets in chronological order is that of 1472. Another investigator of comets, Holetschek,[6] devoting his attention to the size and brightness of comets, began with the comet B.C. 12 and carried out his investigations up to the year 1835 except for a few later periodic comets. It should be noted that modern technique as applied to the photographs of the tails and spectra of comets has given us much better means of information on the physics of comets than was available fifty years ago. The progress in the measuring of

the brightness of comets is doubtful, except for the better magnitudes of comparison stars. However, so far as the complex and elusive details of the structure of the nucleus and the head are concerned, no progress at all is discernible within the last one hundred years. Drawings of Halley's Comet in 1835 made by Bessel far surpass any photographs of the same comet in 1910 obtained with the most powerful instruments. The situation here is, of course, analogous with that of planetary surfaces, where a refractor of moderate size in moments of good seeing may reveal much more than photographs made with the largest reflectors.

One of the problems the solution of which depends necessarily on the already accumulated observational material is the brightness of comets. The writer has just completed an investigation on systematic errors involved in the estimates of the brightness of comets[7] and has come to certain conclusions which may be of interest not only to professional astronomers but also to amateurs desiring to make worthwhile contributions to astronomical science. The situation in regard to the total visual brightness of comets is not as hopeless as it may seem, and, moreover, a better organization of observations with quite modest instrumental means is likely to increase our knowledge of this subject very considerably. In what follows, the visual observations of the total brightness are meant. Photographic observations are practically nonexistent, and the brightness of the nucleus of a comet is mostly a matter of instrumental equipment.

The problem of the luminosity of comets has acquired new significance since investigations of the last ten years have shown that interstellar matter either diffused or concentrated in clouds plays a much more important rôle in the universe than had been formerly supposed. Yet in spite of the large amount of observational data relating to the brightness of comets the whole problem has been in a very unsatisfactory state. It is obvious that the estimates of comet magnitudes are affected with systematic errors. Generally speaking, the procedure heretofore has been to combine all observations without regard to their validity. The resulting deductions as to the photometric laws, disintegration of comets, their age, etc., are, therefore, little better than speculation pointing a way to further investigations rather than giving the required information.

As the goal of the investigation is the study of the variation of the comet's light depending on its distance from the sun, and possibly the phase-angle, only comets with a sufficient number of observations were considered. Furthermore, only photometric observations were taken into account; that is, observations based on actual comparison of the total light of the comet with stars of known brightness. Estimates based on mere impression were rejected. All estimates of brightness were reduced to the International System.

With these limitations 4447 observations of 45 comets, between the years 1858 and 1937, were found to be available. In order to reduce

the amount of work and to increase the reliability of the data, these individual observations were combined into normal places. The number of normal places is 675; *i.e.*, 6.6 observations per place. The formation of normal places was made on the basis of the distribution of observations in respect to the time. Care was taken not to combine observations showing a trend during the interval chosen for the normal place. Simple averages were taken since considerable scattering of observations did not indicate the desirability of any more complicated procedure. The deviations of the individual observations from the mean can be considered as due to chance errors of observations, and the p.e. of normal places as an index of the precision of the observations.

The comparison of an extended object with the point-like images of the stars is bound to result in the scattering of individual estimates and in a large systematic difference between observers. When the estimates of the brightness of a comet by different observers vary by several magnitudes, it is surely unwise to combine all observations as given and expect to obtain significant data. A thorough study of the sources of error is, therefore, necessary in order to reduce the available raw material into a homogeneous photometric system. The errors in the photometry of comets may be classified as follows:

a. Effect depending primarily on the aperture of the instrument
b. Method used in comparison of stars with the comet
c. Effect of the background of the sky
d. Meteorological conditions and differential absorption of light
e. Local conditions
f. Unknown sources and personal equation
g. Intrinsic variation in the light of the comet.

a. Effect of Aperture.—It has been noticed by many observers that the estimates of the brightness of a comet depend on the aperture of the instrument used, the comet being brighter with smaller instruments and brightest of all with the naked eye. The commonly given explanation of this effect is the use of a higher magnifying power with larger instruments. Consequently, with a larger instrument, the observer compares with the stars not the whole light of a comet but only its central part. This explanation, however, is hardly sufficient as a similar effect is known in stellar photometry when point images are compared with each other.

So far as comets are concerned the effect of the aperture of the telescope is combined with the effect of magnification. Generally speaking, the higher power with the same instrument will result in a lower brightness for the comet, but the magnifying power used in comet observations is seldom indicated. Due to the general practice, however, of using the lowest available power for the estimate of the brightness of comets, the situation is not so uncertain as it may seem. Instruments used in the estimates of the brightness of comets were divided into five classes ac-

cording to the following scheme:

System 1—naked-eye observations
System 2—observations with binoculars and field glasses
System 3—observations made with small telescopes and finders up to 4-inch aperture
System 4—observations with small telescopes of from 4 to 10 inches aperture
System 5—observations with the largest telescopes.

Corrections were then sought to reduce all observations to the system of finders and small telescopes (system 3). It became apparent in the course of this investigation that there is a strong correlation between the correction evaluated for system 3 of each comet and the difference of aperture between this system and other systems used. It was decided, therefore, to establish a formula by which observations could be reduced to one definite aperture rather than evaluate the corresponding corrections for different systems.[8]

It was necessary to assume (in view of the lack of data) an average aperture of one inch for binoculars and field glasses. The aperture of the eye was assumed to be zero as the human eye cannot be properly compared with instruments, and the zero aperture simply means that no instrument was used at all. Both of these assumptions are quite immaterial in deriving the corrections for the difference in aperture as the main part of correlation is supplied by the difference in the aperture of finders and telescopes.

There is a possibility that the correction to various instruments may depend on time, or, rather, the brightness of the comet, due to the gradual changes in its aspect. Such an effect has been found by Graff[9] for comet 1932 X. However, in this case, as indeed in most cases, a collation of the results of different observers does not confirm Graff's conclusions.

Among the 45 comets considered in this investigation only two, 1900 II and 1904 I, showed the dependence of corrections on time clearly enough to be taken into account.

The correlation between the difference in the aperture of the telescope in inches, Δa, and the difference in estimated magnitude of the comet, ΔH, is based on 1804 comparisons of observations made nearly simultaneously with different instruments. The means of these differences resulted in ninety-one points of Figure 1.

The points representing the correction to the observed magnitude of the comet *versus* the difference in the aperture of the instruments lie on an approximately straight line. The coefficient of linear correlation

$$r = -0.78 \pm 0.03$$

indicates a rather high degree of correlation. The line of regression of ΔH and Δa is given by the direct solution as

$$\Delta H = 0^M.167 \Delta a - 0^M.09;$$

that is, the correction to the observed magnitude of the comet increases

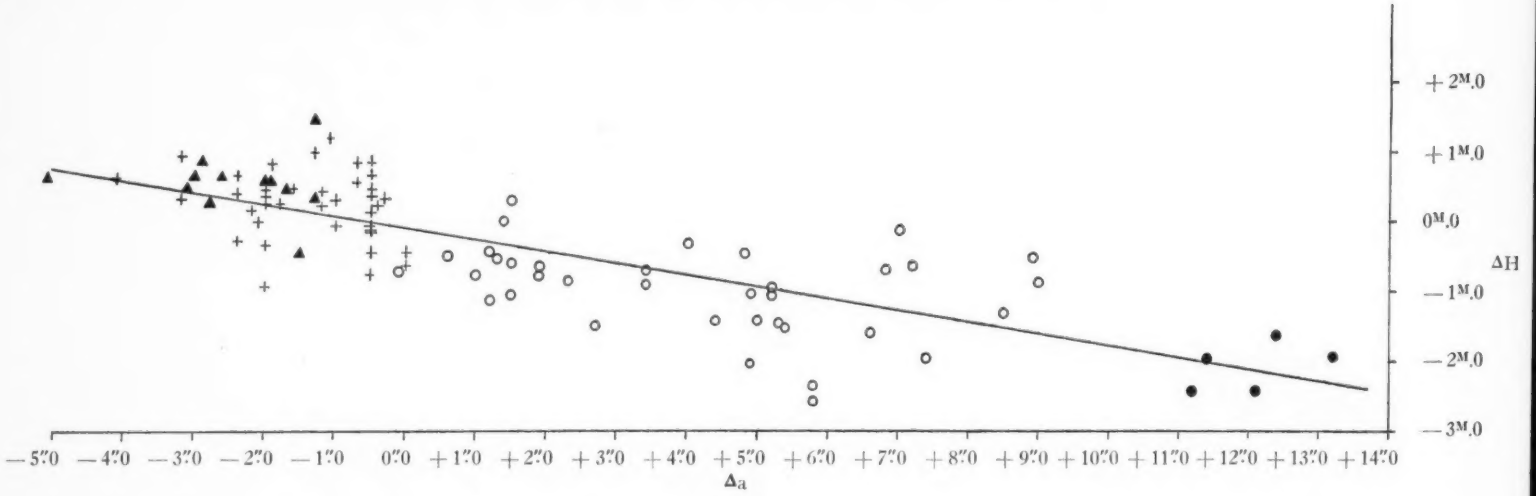


FIGURE 1

FIG. 1. Systematic corrections ΔH depending on the difference Δa in aperture in inches. Triangles represent system 1, crosses system 2, open circles system 4, and filled circles system 5.

numerically with the difference in the size of the instrument by $0^M.17$ per inch of aperture.

It seems that the correlation is not altogether linear. However, the improvement in the line of regression based on a non-linear correlation would be very small and, in view of the uncertainty of some of the data with high Δa, has not been attempted.

The above correlation has been derived for the refractors with a maximum aperture of 16 inches. It is probable that for greater apertures the regression curve deviates more and more from the straight line. There are practically no data for the reflectors. From the few available estimates of brightness made with reflectors it seems that the situation in this case is entirely different.

It is possible, therefore, to make a statistical correction to the published magnitudes of a comet to reduce them to a standard system provided the aperture of the refracting telescope and the photometric system of the observer are known. However, for most of the old observations no such data exist, and we must rely on an empirical correction discussed below.

The effect of the magnifying power of the telescope on the estimates of brightness is not known but must be appreciable. The only available information on this subject is a series of observations by Holetschek[10] and by J. Schmidt,[11] but these refer rather to the nucleus than to the whole comet. From Holetschek's data the following corrections to the power of 112 as compared with the power 26 are obtained:

Comet 1886 I $\quad -2^M.00 \pm 0^M.24$
Comet 1886 II $\quad -1^M.19 \pm 0^M.10.$

There is no systematic variation depending on the brightness of the comet (variation from $8^M.5$ to $5^M.0$), but it appears that different comets may have different values of correction.

Similar results were obtained by J. Schmidt for the nucleus of comet 1874 III observing it with his telescope (aperture not indicated, presumably 6-inch), powers 50 and 300. From his data the correction to power 300 to reduce it to power 50 is $-1^M.59 \pm 0^M.08$.

b. Methods Used.—Probably the most widely used method is that of extra-focal comparison so that the stars have an apparent diameter of the same order of magnitude as the comet. It is obvious that such a procedure may result in a different apparent magnitude of the comet as contrasted with the comparison of the comet with focal images of the stars. From the data of Dziewulski[12] for comet 1932 V, I derive the difference between focal and extra-focal comparisons $0^M.90 \pm 0^M.05$, focal images being fainter. This is the only instance where the direct comparison of these two methods was possible. Most observers are silent as to the exact method used, and no systematic deviation between the focal and extra-focal images has been noticed. Indeed, Bernheimer[13] is of the opinion that extra-focal images result in fainter magnitudes,

and the whole effect may depend on the apparent magnitude, the shape of the comet, etc. If there is any systematic difference between the focal and extra-focal images, it was, of course, absorbed in the instrument correction and, possibly, in personal corrections to different series.

Observations made with special photometers, photoelectric cells, etc., had to be corrected to the average of other observers. The photoelectric cell is the most promising method for the determination of total brightness, but the number of available observations made with it is very small.

c. Effect of the Background.—Some comets are necessarily observed in the early morning or evening hours as well as in moonlight. Diffuse objects like comets are affected by the bright background in an entirely different way from the stars. Presumably the amount of the effect depends on the physical properties of the comet, whether it is condensed or diffuse, whether it is small or large, etc.

This important factor has often been overlooked, and striking results have been obtained. Thus, Holetschek[14] has shown that the remarkable variation in the brightness of Encke's Comet ascribed to the eleven-year solar cycle is, in all probability, due to the situation of the comet in respect to the observer, bright and faint apparitions depending on the situation of the comet in respect to the sun.

Several investigators found a strong correlation between the phases of the moon and departures from the computed curve. Wirtz found for comet 1908 III the probable error of one observation $\pm 0^{M}.40$, but, when the correction due to the light of the moon is applied, the p.e. became $\pm 0^{M}.18$. There is a suggestion of a correlation between the fluctuations in the brightness of the comet and lunar phases for some comets investigated by Philippov.[15] In the present study an introduction of the lunar term with the amplitude of $0^{M}.06$ for comet 1936 *a* has considerably improved the residuals from the photometric curve.[16]

d. Meteorological Conditions.—It is obvious that the state of the sky should affect differently stars and extended objects like comets and nebulae. There lies the danger of the estimate of the brightness based on mere impression. With an experienced observer this "memory scale" may give reliable results unless the sky is not perfectly clear. In the actual comparison of the comet with the stars at least part of this effect is allowed for. It is not safe to make conclusions as to the variability of the comet's light unless the observations extend throughout several hours.

The corrections for the extinction of light in the terrestrial atmosphere are based on the observations of stars, and there is no guarantee that the same formulae are applicable to comets. There are no data on comets to settle this question, but in the observation of nebulae Wirtz[17] found an appreciable difference between the extinction of light shown by the stars and by the nebulae. As some comets must be observed at

their maximum light near the horizon, the insufficient allowance for the atmospheric absorption of light may result in estimating them as too faint.

e. Local Conditions.—Effects of the smoke and haze of a large city are often quite noticeable. At higher altitudes comets appear much brighter. This was generally the experience with Halley's Comet which was observed from high mountains and even from balloons. Bernheimer[18] found that comet 1932 V appeared brighter by $0^M.5$ in the mountains (altitude 700 meters) than in Vienna. For comet 1936 *a* it was found necessary to make an empirical correction of $+0^M.5$ to the observations of Soloview[19] made at a high altitude (2215 meters) as compared with his previous observations made at a low altitude. The number of high altitude observations is, of course, small, and they were all reduced to the average of nearly sea level observations.

f. Unknown Sources.—It is admitted that after all possible sources of error in stellar photometry are taken into account there are still left some obvious errors which it is impossible to trace to any definite cause. They may be caused by the difference in eye sensitivity at different epochs, or even within a few hours, or by preconceived ideas about the object to be measured.

It is to be expected that comets which vary in brightness and shape would furnish even more obscure sources of error in the estimates of their brightness than the stars. We give here two examples of such errors.

For comet 1930 III Iwanowska and Dziewulski,[20] using the same instrument and the same comparison stars under conditions as nearly identical as possible, obtained considerably different results, the average difference (regardless of sign) from 14 estimates being $0^M.19$. Under similar conditions Wirtz and Hellerich[21] obtained for comet 1919 III values differing by $0^M.40$ on September 20 and $0^M.51$ on September 22. Most of such differences may be ascribed to the personal equation of the observer and the care with which observations were made.

g. Intrinsic Variation.—Estimates of the brightness of comets are so fraught with systematic and accidental errors that extreme caution is necessary in attributing the difference in brightness in a short period of time to a real change in brightness. In fact, the change in brightness in a few hours must be assumed only if no other explanation is tenable. Nevertheless, there is no question that comets do change in brightness in a very short interval. The most remarkable example of such a change is the increase in brightness of the nucleus of comet 1884 I by $0^M.53$ in 70 minutes and subsequent decrease by $0^M.33$ in 29 minutes observed by G. Müller[22] on January 1, 1884. The total amplitude of the outburst was estimated by Müller at $1^M.3$ in four hours and forty minutes during which time the comet was under continuous ob-

servation. Sudden increases in brightness of the same comet occurred also on September 22, 1883, and January 13 and 19, 1884.

Empirical Corrections

For most comets observations of the magnitude are given without any indication of the photometric scale or instrument used in estimates. Such observations may be reduced to the photometric system of this investigation by means of empirical corrections. These corrections have been obtained by combining the difference in the normal places between the magnitude H′ given by the observer and the magnitude H finally adopted, taken at intervals of half-magnitude. The result is given in Figure 2.

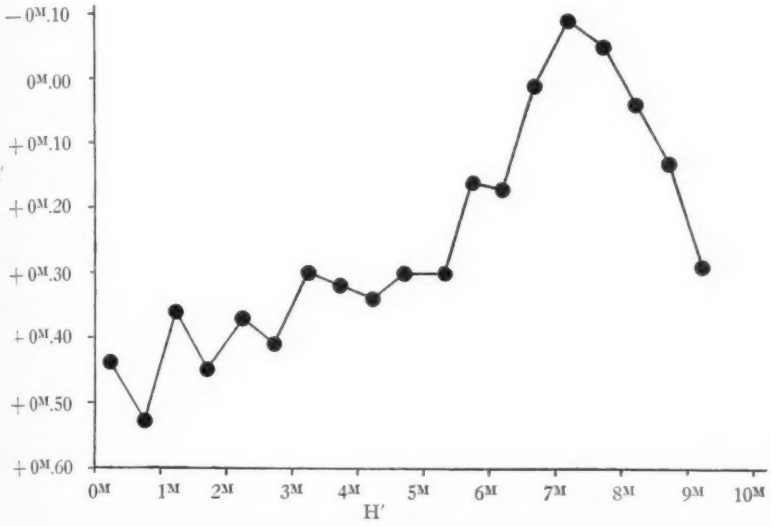


Fig. 2. Systematic corrections ΔH′ to observed magnitude H′ in order to reduce it to a common photometric system.

Between the magnitudes 0M.0 and 9M.5, the corrections to the observed magnitudes are by no means scattered at random as might be expected. The curve represents the corrections due to the reduction to a uniform photometric scale (International System) and reduction to the average instrumental equipment (aperture 2.67 inches). Its general features can be interpreted in the following way. From 0M.0 to 5M.5 we have to deal mainly with naked-eye observations which make the magnitude too bright, and the correction is, therefore, positive. From 5M.5 to 8M.0 the observations are made with small telescopes or finders of nearly the same size as that adopted as standard. The correction is, therefore, small. From 8M.0 to 9M.5 many observations are made with larger tele-

scopes requiring a negative correction. Most observations are made, however, on the B.D. scale requiring a large positive correction. The resultant correction is the combination of the two. Corrections for magnitudes fainter than $9^M.5$ cannot be determined. They are based on a comparatively few observations made by few persons who put special efforts into establishing a photometric scale. Therefore, they constitute material essentially different from the photometric material for magnitudes brighter than $9^M.5$.

TABLE 1

EMPIRICAL CORRECTIONS TO OBSERVED MAGNITUTDE H′

H′ M	ΔH M	H′ M	ΔH M
0.0	+0.45	6.5	+0.07
1.0	+0.44	7.0	—0.03
3.0	+0.41	7.5	—0.09
3.0	+0.37	8.0	+0.01
4.0	+0.32	8.5	+0.11
5.0	+0.25	9.0	+0.22
5.5	+0.21	9.5	+0.30
6.0	+0.15		

Table 1 gives the empirical corrections derived from the smoothed curve based on the data of Figure 2.

PRECISION OF OBSERVATIONS

There are very few data on the precision of individual observations as most observers give only the final results. The 324 observations available for the determination of probable error of observers do not indicate any correlation of p.e. with the magnitude of the comet or with the instrument used. The average p.e. for one set is $\pm 0^M.05$ which is surprisingly small. Since the average number of observations entering into the determinations of H′ for each night is 4.8, the average p.e. of a single observation is $\pm 0^M.11$, which compares very favorably with the average p.e. of catalogues of nebulae.

These data refer, however, to brighter comets. Nothing is known about fainter comets, and, in view of the uncertainty of photometric scales for magnitudes fainter than 8, the data become less reliable for fainter magnitudes.

Considering the small p.e., $\pm 0^M.11$, of individual series, the average p.e. of a single observation for a combination of all observations, $\pm 0^M.21$, seems to be excessive. Comets, however, are not an exception in which the combination of different series results in a much larger p.e. The situation is the same with the magnitudes of nebulae or even with the seemingly exact observations of meridian positions of stars.

The reduction of all comet magnitudes to a uniform scale resulted generally in a considerable better agreement of individual data as can be seen from the following comparison:

Average p.e. of a normal place	H′	$\pm 0^{M}.118$
Average p.e. of a normal place	H	$\pm 0^{M}.089$
Average p.e. of one observation	H′	$\pm 0^{M}.30$
Average p.e. of one observation	H	$\pm 0^{M}.21$

H′ here is the magnitude of the comet given by the observers, and H is the magnitude reduced to the uniform photometric scale discussed above.

Comets and Nebulae

Nebulae and globular clusters are the only classes of celestial objects which can be properly compared with comets in respect to the difficulties of their photometry. It should not be overlooked, however, that nebulae and clusters do not present such difficulty as the comets.

There are several visual photometric catalogues of nebulae and clusters, the most extensive of which is that of Holetschek.[23] The instruments used by Holetschek for his study were the same as used by him for comets so that the comparison is doubly significant. The average p.e. of a single observation for 41 of Holetschek's nebulae was found by Hopmann[24] to be $\pm 0^{M}.19$ which is practically identical with the average p.e. of a single observation $\pm 0^{M}.21$ for comets found in the present study.

Wirtz[25] gives for his catalogue the p.e. of one observation $\pm 0^{M}.09$. Measures by Graff[26] indicate the average p.e. of the mean $\pm 0^{M}.11$ and in a p.e. of one observation, $\pm 0^{M}.31$. Lundmark,[27] on the basis of 25 determinations of the brightness of M31, found p.e. of one determination $\pm 0^{M}.10$, that is, of the same order of magnitude as in individual observations of comets.

If we consider now the systematic errors in the photometry of nebulae, we find a situation analogous to that of the photometry of comets. The problem of reconciling various catalogues of nebulae has been undertaken by Hopmann, Wirtz, Graff, and, especially, by Bernheimer.[28] The corrections from one system to another are large and, what is more important, depend on instruments and methods used.

The general conclusion from this comparison is that the brightness of nebulae can be determined with a somewhat greater precision than the brightness of comets. However, the difference is not large, and, in view of the greater accessibility of nebulae and their constancy of light, is surprisingly small.

Practical Considerations

It should be evident from the above that estimates of the brightness of comets are not a hopeless task. Requiring very modest instrumental means any amateur astronomer can substantially contribute toward our knowledge of comets provided necessary care is taken in observing and in the recording of the observations. For such a conspicuous and well-situated (for the northern hemisphere) comet as 1936 *a* we have only 346 reliable estimates of its brightness. Ten times as many observations (especially from the southern hemisphere which has supplied only seven

observations) would have resulted in a much better photometric curve.

I venture to give here a few suggestions for the observations of the total brightness of comets based mostly on my own experience.

(1) Use the lowest power equipment available. Up to the 5^M comparisons should be made with the naked eye, between 5^M and 8^M with binoculars, and after that with finders of larger telescopes. If several instruments are used, observations should overlap for some time to give the systematic difference between the instruments.

(2) The comparison stars should be identified before the observation begins. The position and approximate magnitude of the comet can be obtained from the *Harvard Announcement Cards* from other sources. The comparison stars should be both fainter and brighter than the comet. Three or four stars are sufficient. The stars should be at approximately the same altitude as the comet to avoid differential absorption effects. This is not always possible with bright comets, but there should be no difficulty with comets fainter than fourth magnitude. Since comets are usually bluish, stars not later than F type should be used for comparison.

(3) The comparison of the star and the head of the comet should be made by putting the binocular or telescope out of focus until both objects appear to be of about the same diameter. With some practice this is not difficult. Any more complicated procedure does not seem to be desirable.

(4) If possible, comparisons should be made several times during the night, say each hour, and if the comet is definitely found to be variable in brightness this fact should be announced at once.

(5) In publishing the observations full details about the instrument, method of comparison, state of the sky, etc., should be indicated. If no Harvard magnitudes are available for fainter stars but the stars have been identified, these observations should be published, as the magnitudes may later become available.

REFERENCES

[1] C. Doris Hellman, "A Bibliography of Tracts and Treatises on the Comet of 1577," *Isis*, **22**, 41, 1934.

[2] James Howard Robinson, "The Great Comet of 1680, A Study in the History of Rationalism," Northfield, Minn., 1916.

[3] *Harvard Observatory Annals*, **3**, 1862.

[4] "Astronomische Beobachtungen über Cometen," *Publ. de l'Obs. d'Athènes*, 1 seriè, Tome **1**, 1863.

[5] R. Jaegermann, "Bredichin's Mechanische Untersuchungen über Cometenformen," St. Petersburg, 1903, p. 390.

[6] "Untersuchungen über die Grösse und Helligkeit der Kometen und ihrer Schweife," Wien, 1896-1917.

[7] *Contributions from the Perkins Observatory*, No. 15, 1941.

[8] This supercedes the preliminary results reported in *Publ. A.A.S.*, **10**, 6 1940.

[9] *Mit. Sternwarte Wien*, No. 3, 103, 1933.

[10] *A.N.*, **115**, 41, 1886.
[11] *A.N.*, **87**, 32, 1875.
[12] *Bull. Obs. Vilno*, No. 15, 1934.
[13] *A.N.*, **248**, 195, 1933. See, however, a different view of Beyer, *A.N.*, **250**, 233, 1933.
[14] "Untersuchungen über die Grösse und Helligkeit de Kometen, etc.," **4**, 41, 1916.
[15] *Russ. A.J.*, **4**, 302, 1927.
[16] *Publ. A. A. S.*, **10**, 6, 1940.
[17] *Med. Lund O.*, II, No. 29, 18, 1923.
[18] *A.N.*, **248**, 195, 1933.
[19] *Tadjik Obs. Circ.*, No. 29, 1937.
[20] *Bull. Obs. Vilno*, No. 11, 1930.
[21] *A.N.*, **212**, 182, 1921.
[22] *A.N.*, **107**, 381, 1884.
[23] *An. St., Wien*, **20**, 1907.
[24] *A.N.*, **214**, 425, 1921.
[25] *Med. Lund O.*, II, No. 29, 1923.
[26] *Mit. St., Wien*, I, 86, 1938.
[27] *An. O., Lund*, **7**, 118, 1938.
[28] *Cir. Lund O.*, Nos. 5 and 6, 1932.

PERKINS OBSERVATORY, JUNE 13, 1941.

Life on Mars

By W. E. DUCKWALL

The question here discussed is the one which is asked more often than any other by the layman when he is in conversation with an astronomer. Because of the perennial and wide-spread interest in this subject, the literature relating to it is becoming quite abundant. Even though this is so, this paper may present the facts in a new light to some reader, and for this reason the publication of it here is deemed desirable. EDITOR.

Owing to its distance from the Sun, to its thin air and to its long seasons it is often supposed that the surface temperatures of Mars are mostly sub-zero and that the planet can sustain neither vegetation nor animal life. Also with some investigators the spectroscope seems to show lack of water vapor, oxygen, and carbon dioxide in the Martian air. In other hands, however, spectroscopes have shown that these three necessities for plant life exist in considerable amounts in the thin air there. Polar caps of ice and snow are seen to come and go according to season, and the areas of vegetation darken with summer weather and the advent of water from melting ice caps.

According to the law of inverse squares the intensity of the Sun's radiation at the distance of Mars is about .435 of that at the distance of the Earth. Then if we assume that .28 of the Sun's radiation at our distance reaches the Earth's surface and that .25 is retained as effective insolation while .73 of the .435 available at Mars is effective insolation, we find that insolation there is .31 to .25 greater than ours, or 1.27 to 1. There are considerable discrepancies in the albedoes of the several

planets as listed by various authors, but it seems reasonable to accept .75 for the Earth and .27 for Mars. The difference between unity and the albedo is the effective or net insolation for a planet which is, of course, diminished by the law of inverse squares for intensity of solar radiation. The air of Mars admits a greater proportion of heat waves than does our air and would of course permit a greater loss. If reradiation were not too great we could safely assume that the mean annual temperature of Mars is higher than ours of 60F, perhaps 72F, or more.

Mars must radiate as much heat as it receives but the summer day temperatures must be higher than ours. Thermocouple determinations indicate temperatures comparable to ours and highest about noon or somewhat sooner than the maximum occurs here. There is a rapid fall near sunset which is undoubtedly due to a blanketing of the warm surface with mist or fog rather than actual cooling of the surface itself. This is indicated by the fact that the belts of water around the melting polar caps are not observed to freeze up at night.

It is probable then that the respective albedoes of the two planets indicate their heat as well as their light retaining ability so that Mars may well have a higher mean annual temperature than ours; and furthermore the Martian surface resembles a vast plain and insolation there should act differently from that on the Earth's surface which is three-fourths water with the land surface broken up into mountain chains and valleys which we know to be subject to cooling by convection and air drainage. Our vast seas afford means of cooling by evaporation beyond anything possible on Mars, and with the effect of less air currents on the temperature of Mars we thus have two unknown factors, so that it is rash to say that Mars is unduly cold or that temperatures fluctuate greatly.

Lowell, in his "Mars as the Abode of Life," pages 240-255, deduced a mean annual temperature of 47F for Mars after allowing for all known factors. Lowell in both text and notes treated the subject of air pressure and temperature rather thoroughly but it is probable that his results are too low for it is not certain that the albedo of Martian air is as low as .17 and he states that we are not certain about the action of air on heat waves of long wave-length.

Mean annual temperatures are of course means and do not indicate what maximum and minimum temperatures may be. We often have maximum summer day temperature of 120F in desert or semi-desert areas 20 degrees north or south of the equator, and 70-90 below zero for land areas near the poles. On Mars the range of temperature is no doubt greater and may range from 150F in tropical desert areas to —120F near the poles in winter but in the regions of vegetation in the temperate zones 40 degrees north or south the temperatures are certainly more equable.

Any planet after its surface has become suitable for life to exist, must radiate as much heat as it receives, else it would become too hot for

existing life and conversely if it radiates more heat than it receives it would soon freeze up, conditions intolerable for most forms of life. Therefore, there must be some automatic means of control of surface and air temperatures.

The heat of the Sun varies in a narrow range over the sunspot cycle, and owing to the capriciousness of weather, temperatures fluctuate greatly, but within safe limits for life on Earth. On Mars, owing to thin air, orbital eccentricity, and longer seasons, temperature fluctuations may be serious unless curbed in some way. Fogginess or cloudiness caused by a drop in temperature would blanket the surface of the planet and tend to check radiation of surface heat. The telescope indicates that Mars does have foggy or misty nights, because the mistiness lasts well into the forenoons. As the Sun gets higher the mists rapidly clear away, thus permitting necessary insolation. If heat were increasing perhaps dust floating high in the air, or high fleecy clouds might temper sunshine as a compensatory measure against too high a temperature. However, plants and animals have compensatory defenses against temperature fluctuations as is well known, but the variations must be within safe limits. The mean annual temperature of the Earth has not varied beyond safe limits within historic times for we have within our air various means of protection against dangerous fluctuations, and Mars too has similar means of protection. The important feature is that such means must operate automatically like a good thermostat to insure a livable temperature.

Convection or vertical currents in the air would tend to reduce surface temperatures, while surface winds act to distribute heat or cold over the surface. But vertical currents increase with the increase of surface heat and decrease with cold. This action is complicated by storm movement on the Earth but probably to much less extent on Mars. We often have prolonged spells of high temperature in summer, due to stagnant air conditions which seem to check convection, so that the air serves as a blanket to retain heat. Such conditions often break up in a series of local thundershowers that bring temporary relief from the heat. Low temperatures without wind movement are not a serious menace to animal life but it is well known that a strong wind is equal to a 30 degree drop in temperature in causing discomfort.

Stagnant air and unobstructed insolation will cause a rise in temperature while cloudiness and convection currents lower it.

The surface albedo of a planet is not a true measure of heat loss into space, since heat waves are known to be retained by media which are entirely transparent to the shorter waves of light rays. The mistiness or fogginess of the night air of Mars should serve also as a blanket against rapid radiation into space in the absence of the Sun. Research with thermocouples seems to substantiate the deduced surface temperature of Mars. Some authors, while admitting the polar caps melt, claim that the surface temperature is 32F, which is true of the melting ice,

but we know snow and ice do not melt until the free air temperature is near 45F or above. The ice caps of Mars melt rapidly enough to form considerable belts of water around their margins, which means, judging from what we see during our thaws, that there is a free air temperature of at least 60F or a warm rain falling on the snow and ice. Conditions on Mars have been compared to those on our high mountains where the air pressure is below 10 inches of mercury. This is fallacious reasoning since snow and ice do not melt on our high mountains even under the equator. The surface of Mars is not mountainous but is surprisingly smooth so that its climate is probably more like that of our extensive and low lying plains, which may become rather hot when the weather is fair. Mars has no large bodies of water to cool the surface by evaporation and reflection, nor is there much cloudiness observable and the planet is exposed to the Sun from pole to pole almost continuously. The axial inclination is about the same as that of the Earth with seasons nearly twice as long, so this would permit long hot summers and long cold winters.

Systematic telescopic observations show that as the warm weather comes on for either hemisphere of Mars the caps start to melt and are surrounded by borders or belts of water, which follow the ice towards the poles. The patches of vegetation and the canals darken seemingly as the water is available and the darkening starts from the belts of water around the polar caps and proceeds towards and beyond the equator. As one wave of growth fades there is another wave starting from the other ice cap, so that for the central zones there seem to be two waves of growth for the long Martian seasons. The dark areas and canals, whose shading varies with the seasons, consist of vegetation and not of water we are certain, but their deepening of tint or darkening is due to the effects of water used in irrigation.

Attempts to detect chlorophyll in the areas of vegetation by means of the spectroscope have not been conclusive, but the color of these areas at their times of maximum development seems a safe guide as to what they are; namely, areas of green leafed vegetation. Vegetation greens up seasonally on Mars much as here, except the wave of growth starts near the belts of water around the polar caps instead of in the equatorial zone as here. That Mars has vegetation we are certain, because we can see it, and that there is animal life is probable, though we cannot hope to see it directly. There are on the face of Mars an inter-connected system of straight lines called *Canali* by Schiaparelli and now considered to be zones of vegetation along waterways that provide, in some manner, water for irrigating the vegetation. Careful observers of Mars have accepted the idea that the straight lines are of artificial origin and that water is impelled along small channels or pipe lines that form a sort of artery or core to these strips of vegetation. Since water will not flow over hills nor very far on a level surface without aid, it seems to be logical to suppose the existence there of an intelligent animal life, cap-

able of constructing pipe lines or channels, of forcing water along such lines and to direct its use for irrigation or other purpses. As the ice caps melt they are surrounded by belts of water that follow the melting ice towards the poles. The action of these belts indicates the existence of vast polar basins which are not completely filled by the caps at their greatest development. The resulting water from the melting ice does not form polar seas nor is it observed to flow away in rivers such as we have. It cannot evaporate rapidly under the damp, foggy conditions attendant upon rapid melting nor is it likely there is percolation or subsurface drainage since the soil of the polar basins is no doubt permanently frozen as are our arctic tundras. Therefore, the water must be pumped out over the rims of these polar basins and into the pipe lines of the canal zones so as to reach the areas where it is needed. Seasonal changes have been observed to take place alternately for each polar cap during the long Martian year, and year after year since Mars has been well seen.

Some authors, disregarding the extensive irrigation systems of prehistoric races, or the more extensive ones of today in various desert areas where water is available, advance various unrelated theories to account for what the telescope reveals on Mars, but no two theories are alike, often they are contradictory and none can account for all the observed facts taken together. The theory of artificiality best accounts for the straightness of the canal zones, their inter-relation and their behavior during the Martian seasons.

Curiously enough the green areas of Mars exceed in extent similar fertile areas on the Earth.

Artificiality, indicated by observation and reasoning, suggests an intelligent and efficient animal life of some kind. The thin air of Mars would not supply enough oxygen to sustain mundane animal life, nor would the low air pressure permit it to exist very long if suddenly transported there.

It may be shown that the energy needed to perform work against gravity is in proportion to the square of the force of gravity acting at the place where the work is being done, so that therefore, work is about seven times easier to perform on Mars than here. Without assuming that Martian animals have much greater extent of lung tissue than mundane animals or that such tissue is more efficient we can see that if Earth animals transported to Mars could survive the low air pressure the small supply of oxygen need not be a serious handicap. Futhermore, since oxygen is heavier than nitrogen it is probable the ratio of oxygen to nitgrogen is as great there as here. Therefore, for a life used to conditions there the low surface gravity may compensate for the small supply of oxygen and existence may be easy and pleasant, unless hampered by long cold winters in the subpolar zones. Since surface gravity is low and the surface level and smooth so that transportation must be easy and rapid beyond what we are used to, it is probable the

animal life in the subpolar zones migrate for the duration of the long cold winters to an even greater extent than is usual for our migratory birds and animals. Then of course hibernation of some sort may be adopted and because of the general clearness of the skies solariums or glassed over structures may render existence more than bearable for the ten months or so of winter. In the tropics and lower temperate zones the weather would certainly be more equable and less stormy than here.

Vegetation on Mars need not differ so greatly from Earth forms since sunlight and heat at the surface are at least as great as here and the periods of growth are similar in spite of long seasons. Vegetation need not vary in stature or sturdiness since the rise of sap in plants is due to capillarity and osmosis and is independent of gravity. The thin air there would seem to preclude destructive storms or high winds so that trees could safely grow taller than here. The thin air suggests need of great wing spread for birds and aircraft, but low gravity and absence of destructive wind storms would offset such a handicap. The size of leaves of plants could vary as freely as here, so far as insolation and wind storms are concerned.

The air pressure is low so water must boil at lower temperatures than here. Lowell's calculations indicated an air pressure of $2\frac{1}{2}$ inches for the Martian surface and a boiling point for water of 110F. It is probable the air pressure there is not greater than 4.2 inches, which would raise the boiling point somewhat, but not enough for open air cooking. Pressure cooking then is needed for foods like ours and for proper sterilization of food and other products. Unless, of course, Martian starch cooks at lower temperatures than ours and bacteria are more easily killed.

It is improbable but not impossible that in some degree Martian animal life resembles mundane fauna. It is certain that the light and heat at the surface are as great or greater than here, so the eyes need not be unduly large. The mean annual temperatures are moderate so there is no need for unusual coating of fur or feathers. Sound waves would be feeble there owing to low air pressure so the range of hearing is quite limited, unless Martian ears are of special development.

The range of variation between life forms is probably less there than here, and evolution may have been more rapid so that there are fewer races but with a high level of development.

The dominant race on Mars must have efficient paws or hands, and brains to direct and plan. This race may not be man-like but such a form is as probable as any other, and much more so than that it should take the form of some of our lower life forms that live by instinct instead of reason.

BIBLIOGRAPHY

Other Worlds Than Ours, Proctor.....London, 1870
Mars, Lowell.....Houghton, Mifflin & Co., New York, 1895
Mars And Its Canals, Lowell.....TheMacmillan Co., New York, 1906
Mars As The Abode of Life, Lowell.....The Macmillan Co., New York, 1908

Mars, Pickering.....Badger, Boston, 1921
Mars And Its Mystery, Morse.....Little, Brown & Co., Boston, 1906
The Riddle of Mars, Housden.....Longman, Green & Co., London, 1914
Percival Lowell, Leonard.....Badger, Boston, 1921
Biography of Percival Lowell, A. Lawrence Lowell.....
.....The Macmillan Co., New York, 1925
Life On Other Worlds, Jones.....The Macmillan Co., New York, 1940

There is also a great mass of material in papers, bulletins, and lectures bearing on the possibility of life on Mars, which may be found in some libraries where files of astronomical journals and bulletins are preserved.

Recent investigation seems more favorable to a belief in the existence of life on Mars than earlier studies indicated.

HILLSBORO, OHIO.

Planet Notes for December, 1941

By R. S. ZUG

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Standard Time, 6 hours, etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac.*

Sun. Apparent positions of the sun for December 1 and December 31, respectively, are: $\alpha = 16^h\,26^m.7$, $\delta = -21°\,42'.7$; $\alpha = 18^h\,38^m.9$, $\delta = -23°\,8'.6$. The sun is situated in the constellation Ophiuchus until December 18, after which it will be in Sagittarius for the remainder of the month. Winter begins December 22, $5^h\,45^m$, when the sun reaches the winter solstice.

Moon. Phenomena of the moon will occur as follows:

		h	m
Full Moon	Dec. 3	20	51
Last Quarter	11	18	48
New Moon	18	10	18
First Quarter	25	10	43
Apogee	Dec. 2	17	
Perigee	17	14	
Apogee	30	0	

Mercury. Mercury will remain inconspicuous during December. It reaches superior conjunction on December 22.

Venus. Venus reaches its greatest brilliancy on December 29, when its stellar magnitude will be —4.4. It will probably be a more conspicuous evening star than when at greatest elongation in November, since it has moved farther northward, the declination of the planet toward the end of December being —14°. The reader may refer to the January, 1941, issue of POPULAR ASTRONOMY, p. 30, for data concerning the distance, angular diameter, etc., of the planet.

Mars. Mars will still be a very favorable object for telescopic examination during December. By the end of December its distance will have increased to 84,000,000 miles and its angular diameter will have diminished to 10″. However, this planet will be well north of the celestial equator in declination +10° so that profitable observing should be possible.

Jupiter. Jupiter will reach opposition on December 8, at which time its stellar magnitude will be —2.4.

Saturn. Saturn will just have passed opposition and will be an excellent object for telescopic examination during December. The planet will be found moving in slow retrograde motion in the constellation of Taurus.

Uranus. Uranus is also favorably placed for observation in the constellation Taurus. Around December 15, the planet will be located near 14 Tauri, a star of magnitude 6.3 situated about 4½° south of the Pleiades. A chart illustrating the apparent motion of Uranus relative to stars appears on page 34 of POPULAR ASTRONOMY for January, 1941.

Neptune. Neptune reaches western quadrature on December 22, and may be found with the aid of a star chart illustrating its apparent motion, which appeared on page 35 of the January, 1941, issue of POPULAR ASTRONOMY. An occultation of Neptune will occur on December 12, the time of geocentric conjunction in right ascension being $13^h\,32^m0$. The occultation is visible in North and South America, between the limiting latitudes of 20° N. and 50° S.

Asteroid Notes

By HUGH S. RICE

Up to the time of September 1, at least, the asteroid headquarters at Berlin-Dahlem were active in the work of these planets, as is shown by their official bulletins, received formerly via Siberia. At that time, 1539 asteroids had received their permanent numbers.

For a few months earlier in the year, it was noted that the largest asteroids—Ceres, Pallas, Juno, and Vesta—were all observable together, at least during any one night's time. Now, the situation is reversed, none of them being available for observation.

The following ephemerides give positions of the six best situated for telescopic work from November to the first week of January. The ephemerides were computed by the headquarters, the Coppernicus-Institut.

EPHEMERIDES OF ASTEROIDS, FOR 0^h U.T. EQUINOX 1950

	173 Ino	$9^M.9$
	α	δ
1941	h m	° ′
Oct. 21	3 17.6	— 5 52
29	3 12.2	— 6 57
Nov. 6	3 5.9	— 7 46
14	2 59.6	— 8 15
22	2 53.5	— 8 22
30	2 48.7	— 8 8

	10 Hygiea	$10^M.1$
	α	δ
1941	h m	° ′
Nov. 6	4 12.0	+24 56
14	4 5.8	+24 40
22	3 59.1	+24 18
30	3 52.3	+23 53
Dec. 8	3 45.9	+23 27
16	3 40.2	+23 0

	55 Pandora	$10^M.4$
	α	δ
1941	h m	° ′
Nov. 14	5 6.8	+32 33
22	4 59.3	+32 50
30	4 50.9	+32 57
Dec. 8	4 42.0	+32 54
16	4 33.5	+32 42
24	4 26.1	+32 24

	127 Johanna	$10^M.3$
	α	δ
1941	h m	° ′
Nov. 14	5 16.1	+30 53
22	5 9.3	+31 18
30	5 1.3	+31 35
Dec. 8	4 52.5	+31 45
16	4 43.8	+31 47
24	4 36.0	+31 41

144 Vibilia	α	δ	$10^M.1$
1941-42	h m	° ′	
Nov. 30	6 8.1	+24 7	
Dec. 8	6 0.4	+24 27	
16	5 51.8	+24 45	
24	5 43.1	+25 0	
Jan. 1	5 34.9	+25 12	
9	5 28.0	+25 22	

485 Genua	α	δ	$10^M.3$
1941-42	h m	° ′	
Nov. 30	6 16.1	+ 1 52	
Dec. 8	6 10.8	+ 0 59	
16	6 4.3	+ 0 19	
24	5 57.3	− 0 2	
Jan. 1	5 50.4	− 0 5	
9	5 44.4	+ 0 10	

Hayden Planetarium, American Museum of Natural History,
New York, N. Y., October 20, 1941.

Occultation Predictions

(Taken from the *American Ephemeris*)

The quantities in the columns a and b are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under a for the star to be observed; similarly, with the latitude, using b; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

			IMMERSION				EMERSION			
			h m	m	m	°	h m	m	m	°
Date 1941	Star	Mag.	Greenwich C.T.	a	b	Angle E from N	Greenwich C.T.	a	b	Angle E from N
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′										
Dec. 5	130 Tau	5.5	1 18.9	..	..	152	1 42.0	..	..	190
6	74 B.Gem	6.2	7 8.9	..	..	33	7 48.5	..	..	340
7	162 B.Gem	5.6	2 27.3	−0.5	+1.5	89	3 37.5	−1.0	+1.2	272
12	27 B.Vir	6.5	10 20.7	−1.7	−0.3	112	11 40.7	−1.6	−1.2	302
13	91 G.Vir	6.5	11 28.9	−1.3	−1.1	136	12 43.1	−1.9	−0.5	278
15	22 B.Lib	6.4	12 17.1	−0.6	−1.4	157	13 9.3	−2.2	+1.2	248
23	82 Aqr	6.5	20 45.5	−1.7	+1.3	60	22 9.1	−1.8	+0.4	248
27	64 Ceti	5.7	19 58.9	−0.6	+1.8	78	21 7.9	−0.8	+2.0	236
27	ξ^1 Ceti	4.5	21 6.7	−0.8	+2.2	55	22 23.1	−1.5	+1.4	256
29	3 BTau	6.4	5 44.5	..	..	15	6 14.6	..	..	324
30	275 B.Tau	6.5	19 53.8	+0.5	+1.8	53	20 45.7	−0.1	+1.0	281
30	α Tau	1.1	21 5.3	+0.3	+2.5	37	21 53.9	−0.7	+0.7	295
OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′										
Dec. 5	130 Tau	5.5	0 59.7	−0.5	+0.1	130	1 39.8	+0.3	+3.0	212
6	74 B.Gem	6.2	6 19.5	−1.9	+3.2	48	7 24.6	−2.3	−2.5	315
7	162 B.Gem	5.6	2 21.0	+0.1	+1.5	81	3 21.4	−0.4	+1.0	279
12	27 B.Vir	6.5	9 56.7	−1.0	−0.8	139	11 7.5	−1.9	+0.6	272
13	91 G.Vir	6.5	11 17.2	−0.2	−3.1	174	11 58.0	−2.8	+2.6	239
27	ξ^1 Ceti	4.5	20 52.8	−0.2	+2.3	44	21 55.2	−1.0	+1.2	272
28	25 Ari	6.5	7 6.1	−0.5	−0.1	53	8 3.8	+0.1	−1.7	281
29	3 B.Tau	6.4	5 14.4	−1.5	+1.9	32	6 12.2	−1.2	−3.2	300
30	α Tau	1.1	21 9.4	+0.8	+2.6	25	21 43.6	−0.3	+0.1	309
31	318 B.Tau	5.7	10 4.6	−0.2	−1.0	82	11 2.6	+0.3	−1.4	277

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

Dec.	5	BD+18° 1112	6.4	14	58.5	—0.2	—0.8	77	15	53.1	+0.5	—1.6	295
	6	74 B.Gem	6.2	5	38.0	—0.2	+3.7	36	6	26.4	—1.9	—1.2	316
	6	110 B.Gem	6.2	15	20.2	—0.6	—0.4	62	16	7.4	+0.5	—2.3	318
	12	27 B.Vir	6.5	9	52.8	..	..	191	10	4.1	..	..	210
	13	38 Vir	6.2	10	0.1	—0.3	+1.9	74	10	47.1	—0.3	—1.0	329
	28	25 Ari	6.5	6	36.1	—1.6	0.0	68	7	56.0	—1.1	—0.8	258
	29	3 B.Tau	6.4	4	17.6	—1.2	+3.9	21	5	22.1	—3.2	—2.2	295
	31	318 B.Tau	5.7	9	56.9	—0.8	—2.2	118	11	0.5	—0.9	—0.2	240

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

A. A. V. S. O. Meeting: Members and their guests gathered from many points on Friday and Saturday, October 10 and 11, 1941, for the thirtieth Annual Meeting of the American Association of Variable Star Observers at the Harvard College Observatory.

The meeting started as a joint session with the Bond Astronomical Club on Friday evening. The special feature presented was a symposium on Variable Star Observing, with the following program:

Leon Campbell: *Visual Methods of Observing*
Henrietta H. Swope: *Photographic Methods of Observing*
Margaret L. Mayall: *Spectrographic Methods of Observing*
Cecilia Payne-Gaposchkin: *Using the Visual, Photographic, and Spectrographic Observations.*

Following this session the 15-inch East Equatorial was used to view the splendors of Mars and Saturn.

The regular business session of the A.A.V.S.O. began at 9:45 on Saturday morning with reports of officers and committees, elections of council members, and the presentation of papers.

The Recorder's Report, which summarizes the activities of the Association for the year just ended, contained items of interest to members and others. This year marked the ending of three decades of the co-operative observing of variable stars by amateur observers. For the first twenty-five years about 500 variable stars, distributed over the whole sky and mainly of long-period, comprised the observing list. About five years ago nearly 100 more variables were added. Many of the irregular and especially interesting variables have been under observation during all these years: for example SS Cygni, U Geminorum, SS Aurigae, R Scuti, R Coronae Borealis, SU Tauri, S Apodis, RY Sagittarii, and most of the bright novae which have made their appearance during this time. Close to 850,000 estimates of magnitude have been made up to the present time.

One observer, Reverend T. C. H. Bouton, has been contributing observations since 1911, when the Association began its work. L. C. Peltier has been observing since 1918 and has contributed approximately 60,000 estimates in these 23 years. E. H. Jones, with a total of 40,000, has been observing since 1923. J. M. Baldwin, with nearly 35,000 estimates, began to contribute in 1920. R. G. Chandra also began his work in the same year and he has communicated about 29,000 observa-

tions. Nearly a score of observers have been contributing for ten to twenty years.

The lending library has been used considerably, and numerous pamphlets and a few books have been donated to the library. The slide collection, numbering over 1000, continues to be used by members and others for public and private lecture purposes.

The Association has issued to its active members the Bi-Monthly Bulletins, Variable Comments, Reprints of Variable Star Notes for 1940, Julian Day Calendars for 1941, and several numbers of the Harvard Annals which contain the original observations of the variable stars.

The Story of Variable Stars, under the joint authorship of Campbell and Jacchia, was completed during the year and issued early in October.

The side activities of the Association included such programs as Occultations, Nova Search, and Aurorae. The photographic program appears not to have made the progress which had been expected. The Chart Committee continues to function with credit to all its members.

A particular feature at the meeting was the display of the light curves of SS Cygni, extending to a length of more than 70 feet, and depicting the vagaries of this star for 45 years, ever since its discovery by Miss L. D. Wells in 1896. This plot indicates, perhaps better than any other illustration, the great value of co-operative variable star observing.

The annual total of observations, although smaller than in the few preceding years, is still of considerable size, 38,043. C. F. Fernald of Wilton, Maine, made 3133 observations; R. P. deKock of South Africa made 2611; W. L. Holt of Scarboro, Maine, and Tucson, Arizona, 2452; and L. C. Peltier of Delphos, Ohio, contributed 1989 estimates. Others who made 1000 or more observations were Mrs. W. M. Kearons of Fall River, Massachusetts; F. Hartmann of St. Albans, New York; Eppe Loreta of Bologna, Italy; A. W. J. Cousins of Durban, South Africa; E. H. Jones of Goffstown, New Hampshire; Morgan Cilley of Lewisburg, West Virginia; and Edward A. Halbach of Milwaukee, Wisconsin.

Groups of observers are to be found near Portland, Maine; Milwaukee, Wisconsin; Mexico City, Mexico; and in South Africa.

Following the reports of officers and committees, a few timely papers were presented as follows:

The Light Curve of U Carinae: A. W. J. Cousins
An Amateur Constructs the Light Curves: W. L. Holt
Distances of Cepheid Variables in Scutum Cloud: M. Williams
Observations of the September Aurorae: C. W. Gartlein.

The following were elected to serve on the council for two years: Claude B. Carpenter, Winifred C. Kearons, Charles H. Smiley, and Marjorie Williams. The council later elected the following officers for 1941-42:

President, Dirk Brouwer
First Vice President, Roy A. Seely
Second Vice President, Edward A. Halbach
Treasurer, Percy W. Witherell
Recorder, Leon Campbell.

Dr. Helen S. Hogg and Charles W. Elmer, as past presidents, remain on the the council.

Members and their guests were royally entertained at luncheon by Dr. and Mrs. Harlow Shapley.

The afternoon session was held at the Milton Academy in Milton, Massachu-

setts, where, following the presentation of papers, Dr. A. E. Navez spoke on the relation of the academy to scientific endeavor. Later an opportunity was given to inspect the modest, yet modern, astronomical equipment.

The annual banquet was held at the Hotel Continental and was attended by 75 persons. Mr. Charles A. Federer, Jr., outlined the aims and purposes of the A.A.L.A., The Amateur Astronomers League of America. Secretary Rosebrugh read an original poem entitled *A Double Star* in which he paid tribute to Professor Frank S. Hogg, president of the R.A.S.C., and Dr. Helen S. Hogg, retiring president of the A.A.V.S.O.

Dr. Shapley gave his customary talk on *High Lights of Astronomy in 1941* which included reference to the new determination of the astronomical unit by the Astronomer Royal, Dr. H. Spencer Jones, as the result of his study of the nuumerous observations of Eros made during the opposition of 1931. The new value of the solar parallax is $8''.7900 \pm 0''.0008$, which places the sun 100,000 miles farther away from the earth than the previous determination had placed it, at a mean distance of 93,010,610 ±8500 miles.

Another important high-light was the interpretation of the hitherto mysterious lines in the solar corona by Dr. B. Edlen of Upsala, Sweden. Reference was also made in this connection to the successful photography of the solar corona, without the aid of an eclipse, by the coronagraph at Climax, Colorado, operated by Mr. W. O. Roberts.

Dr. Martin Schwarzschild's theory on cluster-type variables in which he has shown that the pulsations in these short-period Cepheid variables may display conspicuously the effects of overtones in addition to their ordinary (fundamental) vibrations. Mr. R. M. Scott's recent work on the application of the theory that has been successful for Cepheids to long-period variables was also mentioned as a marked advance in our knowledge concerning these much-observed variables.

Dr. R. Minkowski's recent treatment of the spectra of some of the supernovae tends to confirm the theoretical work of Dr. F. L. Whipple and Dr. C. Payne-Gaposchkin in which they arrive at the conclusion, from a study of "synthetic" theoretical spectra, that the atmospheres of supernovae consist primarily of the common, light elements, and that the temperatures of these novae are not excessive. In other words they do not differ essentially from ordinary novae apart from the widening and blurring of the spectral lines produced by the high velocities of the expanding gases.

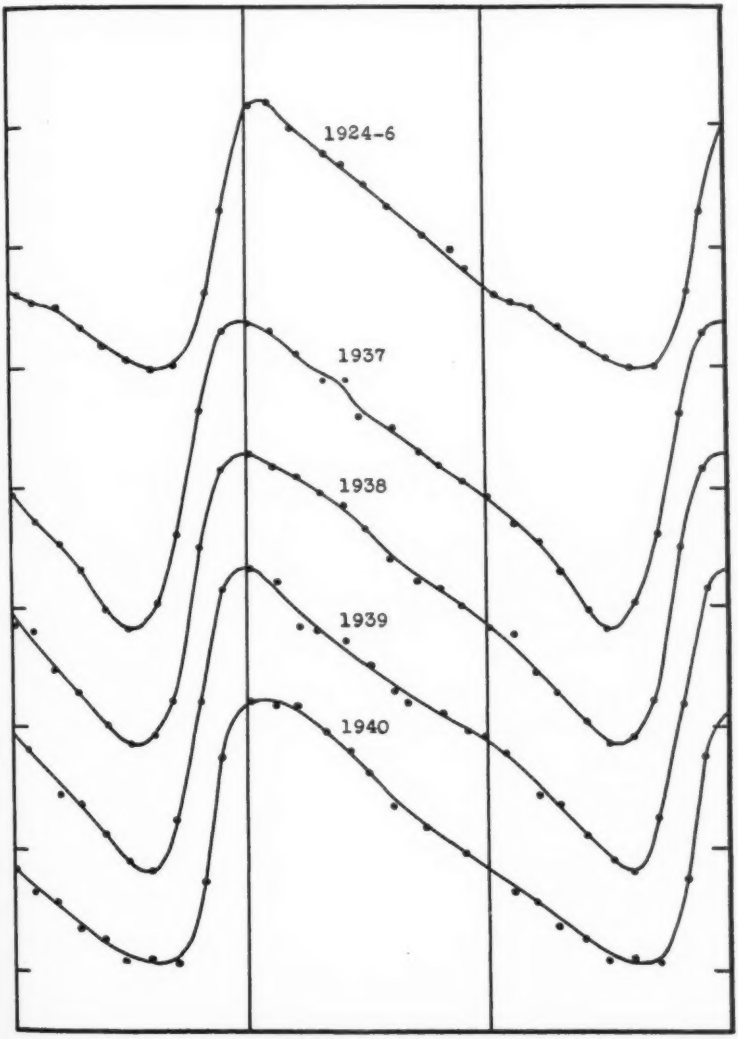
Dr. Shapley also made mention of the recent publication by Dr. R. Prager, in Harvard Annals, Volume 111, of the *History and Bibliography of Variable Stars Discovered During the Years 1931-38,* a continuation of the exhaustive work long carried on by him in Germany.

Mr. Lewis Boss showed an all too short movie-reel of the 1940 Fall Meeting. The climax of the evening came when a selected group of performers presented an extended version of the *Story of Frederick.* This playlet was originally given at the recent meetings at Yerkes Observatory in which the story depicted the adventures of a young astronomer, with the extension referring to what Frederick could do as a member of the A.A.V.S.O.

The meeting adjourned to gather at Pittsburgh, Pennsylvania, for its 1942 spring meeting.

Variable in Telescopium, 185651: A communication from Mark Howarth of Newcastle, New South Wales, containing a series of photographic observations of a star suspected of variability by him in 1936, has been received. The star,

H.D. 17730, R.A. $18^h\ 56^m\ 51^s$, Declination $-51°\ 36'.2$ (1900), was later confirmed as variable from the Harvard plates. Mr. Howarth finds a range of variation between magnitudes 6.6 and 7.7. The star appears to vary irregularly and it will be well worth observing, not only on photographic plates of the past, but in the future.



VISUAL LIGHT CURVES OF U CARINAE

Visual Light Curve of U Carinae: The Cepheid variable U Carinae, 10535$_9$, has been under visual observation by A. W. J. Cousins of Durban, South Africa, during the years 1924-26 and 1937-41 and he communicated a paper on the visual light curves at the recent A.A.V.S.O. meeting.

The star is among the few Cepheids with fairly long period, in this case 38.75 days. Photographic light curves have been published by Hertzsprung and Robinson, but up to the present time no visual light curve has appeared in print. The several light curves as determined by Cousins are shown in the figure.

From an examination of the data given in the table and the figure, one can obtain an idea of the accordance of magnitude at maximum and minimum, and the fact that the period appears to have been subject to slight changes over the years. A. W. Roberts found a period of $38^d.7397$ during the years 1891-99. Between the years 1900 and 1925 the period averaged $38^d.753$, and between 1925 and 1937, $38^d.737$. The recent observations give $38^d.798$. The rapid rise to maximum affords a critical test of the variations in period by determining when the median magnitude has been attained.

The visual range, according to Cousins, is between magnitudes 5.85 and 7.04; the median magnitude is 6.45. The photographic range, according to Robinson, is from 6.39 to 8.34, so that the star is fainter, and the range appreciable greater, in photographic than in visual light, as is to be expected.

	——Magnitude——			Date Maximum		Date Mid point	No.
Years	Max.	Min.	Median	J.D. 2420000+	M-m	of Rise	Obs.
1924-6	5.90	7.01	6.46	4258.3	8.5	4254.7	99
1937	5.81	7.08	6.45	8635.4	8.6	8631.1	141
1938	5.85	7.06	6.45	9022.9	8.4	9018.7	127
1939	5.83	7.08	6.44	9372.1	8.1	9367.9	111
1940	5.88	6.97	6.43	9838.5	8.9	9834.0	130

Observers and Observations Received during September, 1941:

Observer	Var.	Obs.	Observer	Var.	Obs.
Albrecht	9	20	Holt	159	245
Ball, A. R.	21	65	Howarth	14	14
Ball, J.	12	12	Jones	76	334
Blunck	46	53	Kearons, Mrs.	85	200
Bouton	35	50	Kelly	12	19
Brocchi	8	11	deKock	60	347
Buckstaff	18	53	Koons	22	27
Carpenter	28	28	Livingston	67	119
Cave	7	8	Lovinus	16	22
Cilley	30	104	Manlin	45	64
Cousins	80	350	Maupomé	36	36
Dafter, Mrs.	8	26	McKeon	1	4
Diedrich	10	10	Nadeau	31	41
Fernald	204	485	Parks	32	69
Ford	7	7	Peltier	163	277
Franklin	16	24	Pursell	2	4
Geise	7	18	Reeves	2	3
Griffin	39	39	Rosebrugh	11	61
Halbach	158	276	Ryder	8	8
Lange	16	22	Saxon	78	97
Harris	40	40	Schoenke	31	75
Hart	16	54	Sill	37	37
Hartmann	18	20	Smith, F. P.	11	13
Heckenkamp	4	8	Taul.nan	58	101
Hiett	11	20	Topham	40	40

Observer	Var.	Obs	Observer	Var.	Obs.
Townsend	5	5	Wilson	11	11
Toyek	6	6			
Webb	19	23	Total		4082

October 18, 1941.

METEORS AND METEORITES

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD,
Department of Astronomy, University of California, Los Angeles

President of the Society: LINCOLN LA PAZ, Department of Mathematics, Ohio State University, Columbus

Secretary of the Society: C. H. CLEMINSHAW, Griffith Observatory, Los Angeles, and Department of Astronomy, University of Southern California, Los Angeles

Metal Structures in Odessa, Texas, and Canyon Diablo, Arizona, Meteorites*

By J. O. LORD,
Department of Metallurgy, Ohio State University, Columbus

ABSTRACT

The features of structure commonly found in metallic meteorites are described. These include the Widmanstätten structure of the phases kamacite, taenite, and plessite; the mechanical twins, or Neumann bands; strain lines; slip bands; veins; and some non-metallic features, *viz.*, schreibersite and oxide pearlite. Photomicrographs are offered to show these various features as they occurred in a piece of an Odessa, Texas, meteorite and in a piece of a Canyon Diablo, Arizona, meteorite. A discussion of the crystallographic relationships in the various features is offered, with the purpose of throwing possible light on their history and origin. A little speculation is indulged in, regarding an explanation of these structures.

The metallic structural features found in meteorites comprise, with possibly one important exception, all those found or which can be produced in iron or low-carbon steels. These may be listed briefly as follows.

First, the 2 allotropic forms of the metal that appear as separate phases and constitute the well-known kamacite and taenite that are arranged in the Widmanstätten pattern so characteristic of meteorites. These are the same as the α- and γ-phases of steels, known as ferrite and austenite. Ferrite and kamacite are identical; austenite is generally considered to contain carbon in solid solution, whereas taenite is an iron-nickel solid solution of the same crystal structure. The distinction, however, is not sharp, since the iron-nickel alloys may contain carbon and the austenite may contain nickel.

Second should be listed the Neumann bands or twin lines in the kamacite,

*The essence of a paper read at the Seventh Meeting, Columbus, Ohio, on December 29, 1939.

because, next to the Widmanstätten pattern of the kamacite and taenite, these straight, parallel bands are the most striking feature. The twin bands are easily confused with polishing scratches at low magnification but can be distinguished usually by the fact that they stop or change direction abruptly. At high magnification they can be seen usually to have definite area and to vary in width at places along their length.

A third structual feature is the veining which is extremely pronounced in meteorites. This is manifested by irregular lines traversing the kamacite areas and looking like ordinary grain boundaries. These lines are not grain boundaries in the ordinary sense, however, because the areas they inclose are much smaller than the areas of uniform orientation in the kamacite itself. True grain boundaries are lines of separation between areas of different crystalline orientation and origin. As such, they are rare in the meteorites here studied and constitute the exception to steel structures previously noted.

Fourth, evidence of severe strain is found in a few localized places. These strain lines can scarcely be called slip lines, because true slip lines are effaced by polishing the surface. Rather, they are the result of residual stresses in the metal which are partially relieved or unbalanced by grinding or polishing of the surface so that warping or wrinkling occurs. They may be partially explained also as the result of some of the crystalline material being crushed or broken up into an aggregate of very small crystal fragments of different orientation. For convenience they will be referred to simply as strain lines.

Fifth, true slip lines were produced in both the kamacite and the taenite phase of an Odessa, Texas, meteorite section by making an impression with the diamond cone of a Rockwell Hardness Testing Machine. Comparison with these lines helped to identify all the other kinds of lines.

In addition to the preceding, some features were observed in several meteorite sections that are not regularly found in artificially produced iron or steel. Notable among these was a very hard, apparently brittle constituent that occurred at localized spots near the surface of the meteorite, usually in a cracked-up condition and surrounded by, or adjacent to, some non-metallic or oxide phase. This constituent, together with some oxide, frequently extended into the interior of the specimen, in fissures. It was decidedly metallic, its luster being equal to that of the kamacite and having a very slight yellowish tinge.

In the interior of the specimen were noted small crystals of rhombic outline and sharp edges which in apparent hardness and color closely resembled the brittle constituent. These particles are called rhabdites and are probably tetragonal crystals of schreibersite $(Fe, Ni, Co)_3P$.

High magnification revealed a spot in the interior of one specimen that exhibited a laminated structure similar to the pearlite of carbon steel. This is exactly similar to a structure noted by Benedicts and called by him "oxide pearlite." It is supposedly the iron, Fe_3O_4, eutectoid produced by decomposition of wüstite (FeO) at 570° C.

Most iron alloys have their atoms arranged in one or both of 2 space lattices, *viz.*, face-centered cubic (F.-C.C.) and body-centered cubic (B.-C.C.). The relation between the 2 forms is interesting in that the distance of closest approach of atoms in the 2 forms when they are in equilibrium with each other is very nearly the same, so that the change from one form to the other is a change chiefly of atomic position rather than of interatomic forces or stresses.

The iron-nickel alloys of which meteorites are composed exhibit both forms

and, except for nomenclature, are identical with certain nickel-steels of low carbon content. The face-centered form is taenite, if one is talking meteorites, and austenite, or γ-iron, if one is talking steel! The body-centered form is kamacite in meteorites and ferrite in steel. The nickel dissolves in solid solution in both forms of iron. These solid solutions are of the substitution type; that is, nickel atoms merely take positions that would otherwise be occupied by iron atoms in the space lattice. Ni, by itself, crystallizes in the face-centered cubic system with a lattice parameter (p) slightly less than that of γ-Fe: $p = 3.562$Å. for γ-Fe

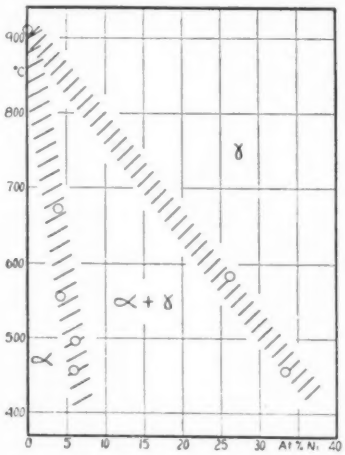


FIG. 1—Equilibrium relationships in α- and γ-iron-nickel alloys, by Jette and Foote.

(estimated) and 3.517Å. for Ni (Jette & Foote). At temperatures between 906°C. and 1403°C., Ni and γ-Fe are soluble in all proportions. The presence of Ni extends the range in which the face-centered form of Fe is stable, so that the γ-form is stable down to ordinary temperatures in alloys containing over 40% Ni. Ni fits easily into the body-centered Fe lattice and thus shows a limited solubility in that form. At 450°C., Jette and Foote estimate between 5% and 8% as the limit of solid solubility of Ni in ferrite (α-Fe or kamacite). The equilibrium diagram proposed by Jette and Foote is shown in Figure 1. The approach to equilibrium between the 2 phases is extremely slow, so that the true boundaries of the α- and γ-fields are still in some doubt. Exact knowledge of these boundaries might throw considerable light on the history of meteorites. Thus, the completeness of the segregation of the taenite areas would indicate the length of time that they had remained at some reasonably constant temperature. The change from the F.-C. C. to the B.-C. C. lattice, upon cooling and with accompanying segregation of Ni into the taenite phase, is the phenomenon that produces the Widmanstätten structure.

The photomicrographs that follow illustrate the structural features mentioned previously. Most of them were made from a section cut from an Odessa, Texas, meteorite belonging to Dr. Lincoln La Paz. Analysis showed this meteorite to

FIG. 2—No magnification; etched in 5% HNO_3 in alcohol (nital). A section of an Odessa, Texas, meteorite showing Widmanstätten structure.

FIG. 3—40 ×; unetched. A brittle constituent; probably schreibersite (tetragonal phosphide) near the surface of the metal.

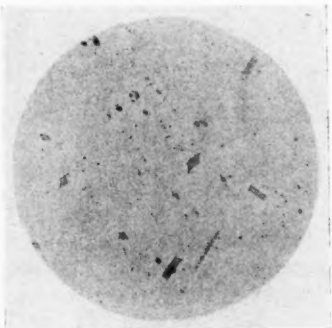


FIG. 4—125 ×; rhombic inclusions (rhabdites); probably schreibersite.

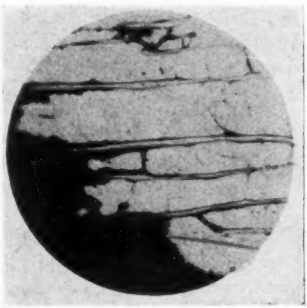


FIG. 5—125 ×; etched in nital. Streaks of taenite outlining Widmanstätten plates of kamacite; oxide penetrating along interface.

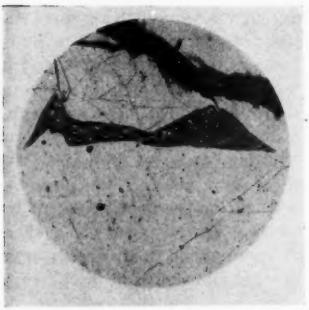


FIG. 6—125 ×; etched in nital. A patch of plessite; *i.e.*, a finely divided mixture of taenite and kamacite.

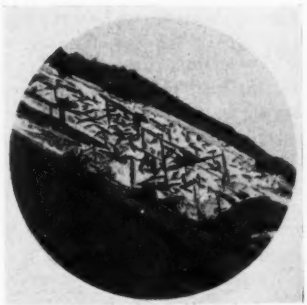


FIG. 7—125 ×; etched in nital. Another patch of plessite with kamacite bands in a Widmanstätten pattern. The oxide has largely replaced the kamacite.

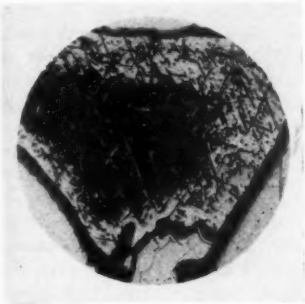


FIG. 8—125 ×; etched in nital. A plessite patch showing a Widmanstätten pattern and banded rim.

FIG. 9—125 ×; etched in nital. The fine lines are twin (or Neumann) bands. **A taenite streak appears in gray. Strain lines appear in the vicinity of an oxide-filled crack. Twin bands and kamacite streaks are distorted in the vicinity of this crack.**

FIG. 10—125 ×. Metal adjacent to indentation produced by a Rockwell hardness diamond cone. **Dark, centered taenite streaks; straight (vertical) twin bands; numerous fine (irregular) slip lines; some veining visible.**

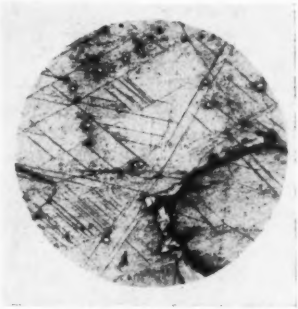


FIG. 11—125 ×; etched in nital. A Canyon Diablo, Arizona, meteorite, showing markings similar to those just listed.

FIG. 12—1220 ×; etched in nital. A spot near a fissure in the center of an Odessa meteorite; shows kamacite plates and "oxide pearlite."

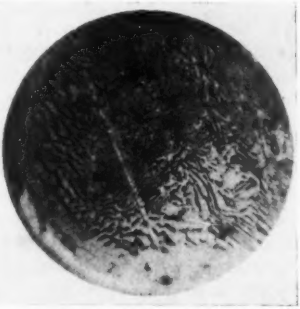


FIG. 13—1220 ×; etched in nital. A similar spot showing well-developed "oxide pearlite."

[In Figs. 2-13, all the magnifications quoted (which apply to the original prints from which these reproductions were made) should be diminished by a factor equal approximately to 3/5.—ED.]

contain 7.14% Ni and about 0.25% Co. Other elements were not determined.

The Widmanstätten structures that involve the taenite and kamacite phases have been very thoroughly worked out by many investigators. Probably the most conclusive works in this matter are the investigations of Dr. Mehl and his co-workers, who have established the crystallographic relationships for conjugate phases in a large number of metallic alloys. They have completely confirmed the work of Kurdjumow and Sachs for iron-nickel alloys. Equally complete work has been done on twinning and slip in these metals by Mathewson, McKeehan, Greninger, and others; veining has been studied by Northcott.

Crystallographically, when taenite is cooled below the upper line of Jette and Foote's diagram (Fig. 1), kamacite forms. This formation takes place by the following mechanism (see Fig. 14). The atoms in a {111} plane in the face-centered cubic taenite lattice change their spacing to those of a {110} plane in

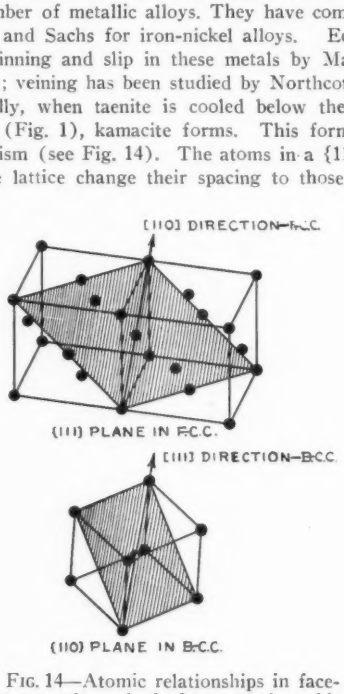


FIG. 14—Atomic relationships in face-centered and body-centered cubic structures.

the body-centered cubic kamacite lattice. They do so by slight shifts in a <110> direction in the face-centered lattice, which then becomes a <111> direction in the body-centered lattice. As soon as a plane is started in the new lattice, the atoms in planes above and below conform to the new arrangement by slight shifts in position, thus forming a plate of the body-centered cubic material.

In the mechanism of Nishyama, the shift is in a <112> direction in the γ-phase. This takes place at very low temperatures (—100°C.). It is the same as the twinning direction in that phase. According to Dr. Mehl, the fact of the transition commencing on a plane of atoms is fundamental, because the plane selected will be the one in which the atom position is very similar in both phases, as in the case just illustrated.

Of course there are 4 different {111} planes in any F.-C.C. crystal and 6 slightly different ways a B.-C. C. crystal can grow on each one of these planes, so that there are 24 possible orientations of the B.-C. C. crystal. The platelet

directions are those of the {111} planes of the face-centered cubic, *i.e.*, taenite, form.

Twinning takes place readily in F.-C. C. crystals but not so easily in B.-C. C. crystals. However, in the meteorites, we are not aware of much twinning in the taenite (F.-C. C.) phase, and the twins in the kamacite phase, while numerous, appear as thin, straight lines. Greninger has shown that while twins occur in pure α-iron (B.-C. C.), as the result of cooling from a high temperature, they are present as massive blocks, often indistinguishable from ordinary grains when so produced.

The lines listed as twins in the structures shown here are Neumann bands and therefore twins produced by shock, possibly the result of impact when the meteorite hit the ground, although it would seem that there could be just as much shock from air pressure ahead, coupled with the expansion of the intense but very local surface temperature while the body was traversing the atmosphere.

Twinning in the kamacite phase is by no means in the same direction as that of the Widmanstätten plates. Whereas these are parallel to a {110} plane, in the B.-C.C. lattice the twinning plane is a {112} plane which cuts the cube diagonally and includes chains of atoms in closest relation to one another. In any plane, however, the chains are separated by greater distances. In twinning, each plane moves in the direction of its chains of atoms a distance over its preceding plane equal to ⅓ the distance between atoms in the chain.

There are 2 other kinds of planes, *viz.*, {110} and {123}, along which motion can and does take place in the case of slip. Hence, twinning in kamacite may be likened to a very limited and special kind of slip.

Slip is noticed as irregular, crossed lines in severely distorted metal, and these are eliminated by repolishing. 2 important differences between slip and twinning are, first, that the slip takes place in block movements; that is, slip occurs on occasional planes, producing an offset at the surface, whereas twinning takes place on a series of adjacent planes by a racking movement. Second, slip leaves the atoms in positions exactly equivalent to their original ones, while in twinning the new positions form a sort of mirror image with respect to the original.

Since slip can take place on 3 planes all passing through the diagonally opposite corners of the cube, the offset or outcrop is rarely a straight line. However, there are distinct groups of directions, so that, crooked as they are, the lines may form intersecting groups at fairly constant angles. Veining has been attributed by Northcott to precipitation of a separate phase, usually oxide, in minute quantities in thin fissures. However, it is strongly suggested by several other authorities that it represents a macro-mosaic structure caused by the slight tilting of blocks of approximately the same crystalline orientation and thereby forming pseudo-grain boundaries. Interesting as they seem, the lines and crystallographic features discussed so far are of slight value in tracing the history of the meteorite.

The coarsely precipitated Widmanstätten structure has, from the first, been offered as proof that the metal underwent extremely slow cooling. It should be noted, however, that well-formed Widmanstätten structures can be produced rapidly if conditions are right. In fact, it has been repeatedly stated and demonstrated that the Widmanstätten mechanism is defeated by cooling that is too prolonged and that the new phase tends either to form at grain boundaries of the old phase, as in steels, or to become spheroidized, *i.e.*, to form rounded grains. Why iron-nickel alloys should be an exception is not quite clear. On the other hand,

it is definitely shown that martensite produced by quenching is a Widmanstätten structure. There is still a possibility that this structure in meteorites has formed at a comparatively low temperature.

The Widmanstätten pattern within the so-called plessite areas, as shown in the photomicrographs, should command our attention. Older authorities attributed the formation of plessite to some sort of eutectoid structure between kamacite and taenite. Exhaustive researches have failed to show any such eutectoid in iron-nickel equilibrium and, furthermore, eutectoids are not known to form definite Widmanstätten patterns of the type shown here; yet the order of magnitude of the kamacite bands that are embedded in the taenite is much smaller than that of the massive kamacite outside of these areas. Indeed, there are numerous examples of artificial iron-nickel alloys that show patterns even coarser than this. This fact strongly suggests that these "plessite" patterns have been formed by heating and cooling, subsequent to the original formation. Heating will cause the taenite areas to increase in size by absorbing more iron. Cooling causes this iron to precipitate again as kamacite, and, logically, in a Widmanstätten pattern. Such a suggestion is well within the realm of possibility, if we consider that, in its travels, the meteorite may have passed close to the Sun or some other star. In that case, the heating and cooling time would have been a matter of a few days or weeks, which would be about right to produce structures of the coarseness shown.

One might speculate further and imagine a mass of material having a constant, albeit eccentric, orbit around the Sun, undergoing such heating and cooling many thousands of times before being finally intercepted by a planet. Such repetitious heat treatment would result, in all probability, in coarse, well-defined structures.

An Unprecedented Frequency of Large Meteors

By H. H. NININGER,
Colorado Museum of Natural History and American Meteorite Laboratory, Denver

Recently our office has received a surprisingly large number of reports of large meteors. We send this note, in order to learn whether other workers have experienced anything comparable.

On September 4, 1941, my son and I were returning from Texas, *via* Highway U.S. 40. At about 7:00 P.M., while there was still considerable light in the west, we noticed a very bright meteor straight ahead as we were traveling in a W.N.W. direction, near Wild Horse, Colorado. Venus was about 30° to the left of it and appeared no brighter than the meteor. At about 8:30 P.M., when we were between Limon and Agate, Colorado, a second meteor of the same magnitude, but this time definitely bluish in color, in contrast to the nearly white light of the first, appeared about due west of us. It descended from our left at about a 50° angle, whereas the first one descended at a steeper angle from our right.

When I arrived at the Colorado Museum of Natural History the next day, Mr. H. C. Markman, the Curator of Geology, reported that on August 29, at 10:12 P.M., while watching a soft-ball game in City Park, Denver, he had seen a very large meteor disappear 25° W. of N., about 30° above the horizon. It descended almost vertically. Though he was surrounded by flood lights, the meteor appeared very bright and of a deep bluish color. He thinks that its brightness compared

favorably with that of a great meteor seen by us on June 28 and that its diameter was about one-third that of the full Moon.

Mr. Roland Thompson and his wife, Dorothy, reported seeing large meteors about 6:00 P.M. on Wednesday, September 3, and again on Friday, September 5, between 6:00 and 6:30 P.M., while in Lakeside Amusement Park, Denver.

Dr. O. R. Sunderland, of Denver, about 1:30 A.M., Sunday, September 7, saw a meteor of extreme size and brightness descend behind the horizon directly south of him. He reported that it was very spectacular, in "spite of a very bright full Moon," and that it gave off abundant sparks. Just before reaching the horizon a large fragment separated from it.

Another person reported seeing a meteor "about 20 ft. long" [*sic!*], as he traveled between Colorado Springs and Pueblo, Colorado, at 8:00 P.M. on September 8.

Mr. Irving Hoglin, who is a good observer, was traveling on Highway U.S. 40 going east into Craig, Colorado. The time was unfortunately not checked, but he is certain that it was between 7:30 and 9:00 P.M. on September 4 when he saw ahead, coming down from his left, a very large meteor which ended in a shower of silvery sparks while still high in the sky. It was about due east of him and may possibly have been the same as No. 1 observed by my son, Robert, and myself from a point near Wild Horse, Colorado. Mr. Hoglin's time is somewhat in error, however, if his meteor was the same as ours.

In any case, it seems that there was an unusual number of large meteors in the interval from August 29 to September 8. In all of my years of experience, never has there been even a near approach to this frequency of reports. Sometimes, when we have had reason to send out press notices concerning an unusual fall, there have come in one, two, or even three reports of "large meteors" in the course of a week, which we have interpreted as a result of the stimulation caused by the press dispatches. In the present instance, there was no such announcement, and none of the reports previously referred to was transmitted to the press. Under these circumstances, we are impelled to look for a more substantial explanation.

The trajectories of the various meteors give no suggestion of a stream. They relate to no radiant, charted or uncharted; yet we are compelled to wonder at their abundance. If, as appears possible, the Earth was passing through an unusually dense swarm of large meteorites in space, then it would seem that other workers must have received some evidence of the fact. We should be glad to hear from them.

[An unusual number of conspicuous meteors has lately been reported also to the EDITOR.]

The Report of the President of the Society for the Term 1937-41*

By H. H. NININGER

The purpose of our Society was set forth at the time of its inception thus: "To promote the discovery, collection, investigation, and preservation of meteorites and to advance the science of meteoritics and related sciences through the increase and diffusion of knowledge concerning meteorites and meteors" (*Constitution*, Art 1, Sect. 2). Today marks the close of the second quadrennium of the Society's existence and the end of my term of service as its President. Consequently, it devolves upon me to report upon the state of our organization.

*Read at the Eighth Meeting, Flagstaff, Arizona, June 23-25, 1941.

In certain respects these four years have been characterized by important advancement. We have held three general meetings (the Sixth, Seventh, and Eighth) in the course of the four years. All of these meetings have been characterized by good programs, which have evoked very keen interest on the part of all of those in attendance. Our CONTRIBUTIONS have been regularly published month by month in our official journal, POPULAR ASTRONOMY, and have been reissued in a bound fascicle at the end of each year. These CONTRIBUTIONS have comprised almost exactly 300 pages and have included 116 titles for the four years. Besides the officially published CONTRIBUTIONS, other equally important papers have been published elsewhere (because of the very limited amount of space provided in our official organ) by our members. These outside publications have been fully as extensive as, if not of even greater volume than, the CONTRIBUTIONS themselves. Thirty-nine members have contributed to the CONTRIBUTIONS in the quadrennium. This relatively large number definitely indicates that our organization is thoroughly alive and active.

Besides participating in our regular meetings and maintaining our publications, our membership has done much to advance meteoritics. I have jotted down a few items of a research nature that have come to my notice and that seem to indicate that we are making headway toward our stated objectives.

1st: 221 meteorite discoveries have been reported to our Committee on Catalog from August, 1936, to December, 1940.

2nd: Two meteoritic dust clouds have been photographed.

3rd: Free copper has been discovered in a metallic meteorite for the first time on record.

4th: Notable advancement has been made in the methods of collecting subsoil meteorites.

5th: For the first time, a large meteorite crater is being excavated (near Odessa, Texas). Incidental to this project, small, associated craters have been discovered and much new information seems destined to be gathered concerning the nature of large meteorites. This work is not officially connected with the Society, but the project was originally suggested and outlined by your President, and the enthusiasm for its undertaking has definitely stemmed from our membership.

6th: Verification of the fall of small meteoritic particles in connection with normal meteorite falls has been definitely established (at Holbrook, Arizona), by the collection of specimens.

7th: A new device, in the form of a "magnetic rake," for the collection of small meteoritic particles has been developed and applied to a new type of survey.

8th: The great Goose Lake, California, meteorite has been discovered and recovered by an S.R.M. expedition.

9th: A better understanding and a better agreement in the use of certain terms, particularly the terms *meteorite, meteor, meteoritic, meteoric, and meteoritical,* as recommended by the Society, have been reached.

10th: We have had official representation at two Pan-American Science Congresses and at the International Astronomical Union, meeting at Stockholm, Sweden, in 1938.

11th: Tektites have for the first time been discovered in North America and

carefully studied by a fellow of our Society.

12th: For the first time, a textbook on geology has appeared wherein several pages are devoted to the subject of meteorites.

13th: Definite flow structure has for the first time been reported in a meteorite.

14th: Courses in meteoritics are now being offered in at least two American universities.

15th: More than a score of new institutions have been added to the comparatively meager number which now possess collections of meteorites suitable for study purposes.

Thus we see that in the matters of discovery, collection, and preservation of meteorites we have succeeded well in carrying out the purposes of our organization. We have made considerable headway also in the increase and dissemination of knowledge concerning meteorites. But we have been *very seriously handicapped* in this latter aspect of our program by lack of funds. *We need our own publication.* We need funds for many phases of research. Looking to these ends, we have appointed a Committee on Endowment. We shall call for a report of that Committee. Regardless of whether the Committee is to be continued or not, this matter of endowment must continue to challenge the Society.

My term of service has drawn to a close. I am not, nor have I been at any time, satisfied with my own work in this office. I have not given it the time it should have had and I have accomplished less than I should have accomplished. But as a result of the exceptionally faithful and efficient services of Secretary Webb and Treasurer Brady, together with the invaluable advice of Ex-President Leonard, we have completed what I think may be regarded as a very successful administration. I thank all of you for your loyalty and support. The work now passes into abler hands and I bespeak for us more rapid progress in the future.

Representative in the Council of the A.A.A.S.

At a meeting of the Council of the Society for the 1941-45 term, held at the home of Treasurer Brady near Flagstaff, Arizona, on the evening of June 25, 1941, immediately after the close of the Eighth Meeting of the Society, President La Paz was appointed, in accordance with Art. 3, Sect. 3, of the *By-Laws*, to continue during the 1941-45 term as the Representative of the Society in the Council of the American Association for the Advancement of Science (see *C.S.R.M.*, **2**, No. 2, 94-5; *P. A.*, **47**, 157-8, 1939). The members in attendance at this, the first meeting of the new Council, were President La Paz, Secretary Cleminshaw, Treasurer Brady, Editor Leonard, Councilor Monnig, and Councilor (Ex-President) Nininger. Ex-Secretary Webb was present by invitation.

C. H. CLEMINSHAW, *Secretary*

Comet Notes

Due to the absence of Dr. Van Biesbroeck from Yerkes Observatory while working at the McDonald Observatory, no "Comet Notes" are at hand for this issue. However, Dr. Van Biesbroeck will be back home in time to prepare the notes for the December issue, and they will appear then as usual. EDITOR.

Notes from Amateurs

The Aurora of September 18-19, 1941

Having watched the progress of a large group of sunspots as they traveled across the face of the sun for several days previous, the writer was not entirely unprepared for the spectacular display of "Northern Lights" on September 18. Soon after dusk on that evening it became apparent that there would be an auroral display, but no indication was visible that it would be of the magnitude which later developed.

The first manifestation was the appearance of the usual type of auroral arch of which the highest portion was fully forty degrees above the horizon and from the upper edge of which a great many narrow streamers of varying lengths emanated. Very little movement was noticed at this time. Below the arch, which was perhaps 2 or 3 degrees wide, was a band of almost impenetrable darkness and below this band of blackness, to the northern horizon, the sky had a normal appearance. At about 8:30 P.M., Eastern Daylight Saving Time, a number of rapidly pulsating waves of faint white light began to move about directly overhead and extended, at times, far to the south of the zenith. At this time the auroral arch was still maintaining the form and position which it had possessed ever since it became visible. The narrow streamers were, if any change occurred, longer and brighter, however.

By 9:00 P.M., the display was entering upon its most active and brilliant phase. A great area of pinkish light had developed at the eastern end of the auroral arch from which, at short intervals, large patches of green and pale blue luminescence were erupted towards the zenith. A similar, and more reddish, area was also visible at the western end of the arch. The entire auroral arch now commenced a slow movement downward toward the northern horizon. This motion continued for nearly two hours and the entire arch had at that time disappeared below the horizon. The whole sky was now filled with rapidly shifting areas of pale colored light which seemed to *shiver* at a fairly high frequency.

Soon it became evident that a coronal type of display was going to be produced. Long curved umbrella-like rays began to reach up from all parts of the horizon and a most irregularly shaped corona appeared. At the same time tremendous *flares* and *explosions* of bluish white and very pale green light silently played about the area directly overhead. At times the effect was like that of a sky-writing aeroplane traveling most erratically and at a terrific speed. Never, for more than two or three second at a time, were the formations the same. In the northwest Ursa Major was scarcely visible through the glow while in the east ruddy Mars peered fitfully through a shimmering roseate fog of light.

In the zenith the awesome celestial pyrotechnics were still furiously going on. By now the arch had covered nearly half the distance from its original position to the horizon. The general illumination was sufficient to read the hands of a watch easily and must have equalled two full moons at least. This activity continued undiminished until 9:40 P.M., after which time it began to decrease in intensity. At 10:10 P.M., the sky was still luminous with gently pulsating streamers and lazily drifting patches of white light. The large area of reddish light at the western end of the arch had now become a brilliant green and had extended itself considerably to the northwest. A similar area in the east had also spread out toward the northeast. Long faint rays of light still crept and wavered over

the northern horizon and occasional faint luminous areas flickered about in the zenith.

At 2:15 A.M., the activity was still slowly diminishing although there was yet a large luminous area in both the east and west and at least a dozen almost motionless streamers rising from a dark cloud bank low in the north. The observatory building and dome were starkly silhouetted against a faintly throbbing milky sky through which, from time to time, a needle-like ray of green arrowed silently. Crickets chirped incessantly and before long the pale fingers of dawn slowly erased the last vestiges of the heavenly fire-works from the sky. A motor truck came rushing along the main highway and the driver threw out a bundle of newspapers. There in black letters was the headline, "Auroral Display Watched by Thousands."

This display was certainly the most active and spectacular since that of January 25, 1938, and probably since the great aurora of March 22, 1920. Teletype and short-wave radio communication was seriously hampered and many people called observatory, newspaper offices, and police stations to find out if the activity had any connection with the European War or the Defense Program.

Observations made on the evening of September 19, after sunset, revealed that a slight amount of auroral activity still persisted and this, although faint, was seen to last until well after midnight.

LEWIS J. BOSS.

Seagrave Memorial Observatory, North Scituate, Rhode Island.

Aurorae and Sunspots

In connection with comments on the brilliant aurora of September 18, mentioned in the preceding issue and also in this one, the Reverend William M. Kearons of Fall River, Mass., submitted a number of photographs showing the movement from day to day of a large group of spots across the disc of the sun. He predicted that the group would probably return about October 5.

Under date of October 22, Mr. Kearons calls attention to photographs made on October 8 and October 11. These show only two spots in the position expected but so small as hardly to be compared with the large group of spots last month. It seems, therefore, that the extensive disturbance on the sun which apparently caused the unusual aurora has subsided quite rapidly.

C.H.G.

Amateur Astronomers Hold Third Convention

The third National Convention of Amateur Astronomers was held in Washington, D. C., on July 4-5. About 125 delegates represented 19 states from Massachusetts to Florida, and Delaware to Illinois.

Dr. Clyde Fisher of the Hayden Planetarium gave the opening address on "The Rise of Popular Astronomy." He felt that people were more astronomy conscious today than they had been since the beginning of the century.

Mr. Charles A. Federer, Jr., secretary of the New York amateurs, urged all societies to unite in organizing the Amateur Astronomers League of America. He read the proposed constitution recommended by the Committee on Permanent Organization and a discussion of it followed. This constitution will be sent to all known societies for ratification or amendment.

Dr. H. F. Johnston, Department of Terrestrial Magnetism, Carnegie Institution of Washington, showed films illustrating his talk on general features of the

scientific program of the Department of Terrestrial Magnetism. Modern study of geomagnetics is proceeding along two lines—the collection of information about the earth's magnetic field, and the study of atomic magnetism.

At a general discussion, 19 delegates reported for societies and groups of amateurs. Several told of their club activities and many said they were trying to educate their communities regarding the difference between astronomy and astrology.

Saturday morning, Dr. Charles G. Abbot, secretary of the Smithsonian Institution, summarized the work being done on solar radiation. In some parts of the country heat from the sun is used for domestic purposes and eventually, he predicted, we may be able to obtain energy to fill all power requirements in the United States. Another branch is the study of the amount and variation of solar radiation.

Mr. C. T. Jones brought a remarkable motion picture from the Barnard Astronomical Society, showing construction of the Chattanooga Observatory, all the steps in preparation of the 20-inch mirror, and assembling the mounting. The observatory is open to the public every clear night. Other films showed the New York amateurs attending a meeting of the A.A.V.S.O. at Vassar, telescope making by the Washington group, and how to "Know Your Money," presented by the U.S. Secret Service.

In spite of heavy clouds, the delegates visited the Naval Observatory (by special permission) to see the 26-inch refractor and 40-inch reflector telescopes.

The banquet Saturday evening at the Willard Hotel drew nearly 150 persons who enjoyed dinner music by the orchestra and informal talks by Dr. Fisher and James Stokley of Science Service, who related their experiences on eclipse expeditions.

The exhibit in the Fairfax Room of the hotel was an important feature of the convention. The number and variety of exhibits marked a wide range of interests among amateur astronomers who devote considerable time and skill to their hobbies.

Class I, photographs of telescopes made by amateurs, drew the most entries. The prize was awarded Robert Sandberg of Detroit, Mich., for his group of pictures showing his 10- and 12-inch reflectors and a 24-inch in the process of grinding. The observatory dome, 18 feet in diameter which he himself built, created quite a stir.

In Class II, telescopes and telescope-making equipment, Edward Hopkins, Elizabeth, N. J., was the winner with what another amateur called " a piece of jewelry," so well finished were the intricate parts of this handsome telescope.

Class III, one-fifth size models of Tycho Brahe's armillary spheres, together with translations of the Latin descriptions and a replica of an ancient telescope submitted by D. C. Eichner, Bloomfield, N. J., were the judges' selection.

Carl F. Alsing's pictures of the lunar eclipse May 14, 1938, won the award in Class IV. He was one of the S.T.A.R.S. of Springfield, Mass., who exhibited a fine panel of photographs.

The prize miscellaneous item of Class V was labeled, "Channeling Dingbat," contrived by William Buchele, Toledo, O. The dingbat resembles a soldering iron and is used to make the grooves in the lap before polishing a mirror.

Corning Glass Works displayed 4-inch to 12-inch Pyrex blanks and a 20-inch replica of the famous 200-inch reflector, together with illustrations of the steps in pouring the glass. The U. S. National Museum loaned an exhibit of stone and iron-stone meteorites. Through the courtesy of the Carnegie Institution several

large photographs of the moon taken at Mt. Wilson and Lick Observatories were shown.

The program for the ladies included a drive past historical points of interest and a tea on Friday, the Library of Congress and National Gallery of Art on Saturday, and a trip to Mt. Vernon on Sunday for all who were interested.

An invitation from the Detroit and Northwest Astronomical Societies to meet at Detroit, Mich., next year was accepted by the convention. The opportunity to see some of the nearby observatories and institutions will attract many delegates. It is hoped that other groups of amateur astronomers will lead future conventions westward. Some represenatives from the east should be able to visit the west to exchange views and experiences and to meet other people whom they now know by name only.

MABEL STEARNS, *Secretary*,
August 1, 1941. National Capital Amateur Astronomers Association.

The New Haven Amateur Astronomical Society

The forty-ninth meeting of the New Haven Amateur Astronomical Society was held at the Yale Observatory on Saturday, September 6. Mr. Donald Kimball, of the faculty of New Haven High School, talked on the subject "Developing the Light Curves of Variable Stars."

He described the photometer which he used to measure the size of the star image on the plate, since the diameter of the image is a function of the brightness. The plate is illuminated through an opening larger than the largest star image. The transmitted light falls on a photo-electric cell, and the resulting current is amplified by a vacuum tube and measured by the scale of a D'Arsonval galvanometer. Readings are taken of the background of the plate, of the star image, and for complete darkness.

Five comparison stars covering the proper range of magnitude, located within one degree of the variable are used. It is necessary to determine the correct magnitude of the comparison stars with the combination of camera and plates used. Mr. Kimball used red-sensitive plates. For this calibration the North Polar sequence is used. This is a series of fifty stars near the Pole, of which the magnitudes and color indices have been accurately determined at Harvard Observatory. The variable field and that of the Pole are photographed on the same plate in as rapid succession as possible. The field of the variable must be at the altitude of the Pole, so that atmospheric conditions will be the same.

It is customary to make five exposures of the variable field on one plate. For any one exposure first the variable is measured, then the comparison stars, then the variable. This means $7 \times 5 \times 5$ or 175 measurements for each plate. Four or five hundred plates are used to obtain a good light curve. From the known magnitudes of the comparison stars the magnitude of the variable at the instant it was observed can be obtained. The light curve is then found in the usual manner. Mr. Kimball then gave the statistics of the star he had particularly studied, SV Camelopardalis, an eclipsing binary with a period of 0.6 days.

DOROTHY JOHNSTON, *Secretary*.

The Cleveland Astronomical Society

Our group was privileged to be the first to view the newly completed Schmidt-type telescope at our first regular meeting on Friday evening, September 26, at the Warner & Swasey Observatory of Case School of Applied Science. The meet-

ing was called in the Warner Auditorium at 8:00 P.M., and Dr. Nassau addressed the Society on the subject "The New Observatory, Its Telescope and Exhibits." This was the twentieth anniversary of The Cleveland Astronomical Society, Dr. Nassau having been the speaker at that first gathering, his subject then being "The Sextant." The planet Mars, observed through the 10-inch telescope, was an interesting object, the polar cap and other markings being clearly defined. The great nebula in Andromeda was also viewed. The twentieth anniversary program notes the following events for the coming season.

October 24. 8:00 P.M. "The Study of Solar Phenomena by Means of Motion Pictures." Dr. Robert R. McMath.

November 28. 8:00 P.M. "Science and Modern Life." David Deitz.

January 16. 8:00 P.M. "Telescopes—Past, Present, and Future." Dr. O. L. Dustheimer.

February 13. 8:00 P.M. "Problems in Stellar Traffic." Dr. S. W. McCuskey.

March 13. 8:00 P.M. "Astronomy and the Spectroscope." Dr. Cedric E. Hesthal.

April 10. 8:00 P.M. "Fifty Years of Astronomical Progress." Dr. Keivin Burns.

May 8. 8:00 P.M. "Variable Stars." Dr. Cecilia Payne Gaposchkin.

The meeting of January 16 will be at Baldwin-Wallace College, Berea, Ohio. All other meetings will be at the Warner Auditorium of the Observatory, Taylor and Brunswick Roads, East Cleveland, Ohio.

DON H. JOHNSTON.

Euclid Beach Park, Cleveland, Ohio.

General Notes

Dr. John S. Plaskett, for many years the director of the Dominion Astrophysical Observatory at Victoria, B. C., died on October 19 at the age of seventy-five years.

Mr. James Stokley, formerly director of the Fels Planetarium and later of the Buhl Planetarium, has joined the staff of the General Electric Company. In his new position Mr. Stokley will interpret, for the public, the important work that is being done in the General Electric Research Laboratory.

The Amateur Astronomers Association of Pittsburgh held its regular meeting in the Lecture Hall, Buhl Planetarium Building, on Friday, October 10, 1941. The speaker was Mr. Leo J. Scanlon, on the topic "Shakespeare and Astronomy."

The Rittenhouse Astronomical Society, of Philadelphia, held a special outdoor meeting on Friday, September 26, at which time the members of the Society and their friends were guests of Mr. Harry B. Rumrill at Tredyffrin Observatory, Berwyn, Pa.

The regular meeting was held on Friday, October 10, at Sproul Observatory at Swarthmore College. The program was presented by the Observatory staff, and opportunity was offered to inspect the instrumental equipment.

General Catalogue of the Bruce Proper Motion Survey

Parts A, B, and C of the General Catalogue of the Bruce Proper Motion Survey, giving the positions, photographic magnitudes and proper motions for 28535 stars south of declination 50° are now being distributed to the subscribers. A limited

number of copies are still available at the original price of $5.00 a set, but no more will be mimeographed if there is no further demand for them at this time. Those interested in procuring a set should communicate with the University of Minnesota Press, Minneapolis.

The Semicentennial of Ladd Observatory

The fiftieth anniversary of the opening of the Ladd Observatory was celebrated by Brown University on October 21 with a reception at the observatory in the afternoon and a lecture in the evening by Professor Frederick Slocum of the class of 1895, formerly professor of astronomy at Brown and now director of the Van Vleck Observatory at Wesleyan University.

The gift of former Governor Herbert W. Ladd of Rhode Island, the observatory was opened on October 21, 1891, after having been built and equipped at a cost of $25,000. Its principal instrument is a 12-inch refracting telescope.

International co-operation between astronomers in all parts of the world has helped to bring about the great advancement of knowledge in the field of astronomical science, Professor Slocum said. Further co-operative steps, he pointed out, will have to wait until the end of the current wars in Europe and Asia.

Professor Charles H. Smiley, director of the Ladd Observatory, announced that the next expedition from Brown will go to South America to photograph the total eclipse of the sun on January 25, 1944. Professor Smiley was in Peru and Brazil in 1937 and 1940 to photograph solar eclipses.

President and Mrs. Henry M. Wriston were among those receiving in the afternoon. An exhibition of early astronomical instruments, including the transit used by Professor Benjamin West at Brown in 1769, was on display.

Providence, R. I.

The Royal Observatory at Greenwich

Following are excerpts of a summary, in *Nature* for July 26, 1941, of the annual report of the Astronomer Royal. He and his staff are to be commended most heartily for the successful manner in which the important work of their institution is being carried on under most unfavorable conditions.

"The annual report of the Astronomer Royal, just published, refers to the work of the Royal Observatory during the period May 1, 1940-April 30, 1941. To those who know the position of the Observatory, in the midst of military and industrial objectives, it will come as no surprise that much of the work has been curtailed by enemy action. The last report mentioned the dismantling of much of the optical apparatus; most of the mirrors and lenses have now been sent away from Greenwich for safety. Since heavy bombing of London started last September, night observations have been impossible on such of the telescopes as had not already been dismounted at the outbreak of hostilities; in fact, the only observing programmes still carried on at Greenwich are daylight ones, namely, the routine meteorological work and the photographic and visual solar observations.

"The public time service functions well from two emergency outstations, as the familiar 'six pips' regularly testify. The Rugby rhythmic signals, however, in present circumstances fall short of the high precision needed for control of frequency standards, though they are, of course, quiet adequate for navigation. Rating of chromometers and watches and their issue to the Royal Navy continue as usual, though the entire establishment concerned has been moved for the second time in two years.

"Work has ceased on the Airy transit circle after continuous observation with

this instrument for ninety years. More than 650,000 observations have been made with it, forming the most important contribution from a single instrument to fundamental positional astronomy. The new reversible transit circle which is to take its place has obtained nearly 10,000 transits during the last three years. When observing ceased in September, 1940, the work of determining the division errors had been completed and an investigation started on the irregularities of the pivots. These latter have already been found to be extremely small.

"The 'Nautical Almanac' office continues its essential work, though it has had to contend with the destruction by fire of the whole of the type and plates for all its publications except the 'Astronomical Navigation Tables.' The consequent delay in publication is being rapidly made good, in some cases by using photographic reproduction in lieu of printing from type.

"Astronomers all over the world will join in sympathizing with the Astronomer Royal and his staff on the interruption of many of their long-established programmes, and in congratulating them on their maintenance of essential services throughout a very trying period."

Book Reviews

The Stereographic Projection, by F. W. Sohon, S.J., Director Seismological Observatory, Georgetown University. (Chemical Publishing Company, Inc., Brooklyn, N. Y. 210 pp. 53 diagrams. Price $4.00.)

As a textbook of the theory and uses of the stereographic projection in various scientific fields this book is a definite contribution. The reviewer was surprised to discover the number of fields in which the projection is of use. The forty pages of tables in the appendix should be of considerable value, particularly to the seismologist.

For the astronomer the projection provides a surprisingly simple graphical method of transforming co-ordinates, say from the equator system to the horizon system, or of solving the astronomical triangle for navigational purposes. One of the seven chapters is devoted to the solution of such problems. In practice, however, the accuracy of any graphical method is usually insufficient. When a low degree of accuracy suffices, tabular methods generally provide a quicker solution. In special cases, however, when graphical solutions of problems in spherical geometry may be desirable, the reviewer recommends "The Stereographic Projection" for serious consideration by astronomers.

The research scientist who wishes to investigate the stereographic projection for possible uses in his field will miss a glossary of the terms used. Unless fairly conversant with the projection he will have to wade through most of the wordy proofs and theorems in the first third of the book in order to appreciate an application in his field. Alternate demonstrations by vector methods are presented for many of the theorems and formulae. To the astronomer these alternative demonstrations will generally seem unnecessary, as may the book itself, except for very specialized problems.

FRED L. WHIPPLE.

Harvard College Observatory.

100 Years of Medicine, by Wyndham E. B. Lloyd. (The Scientific Book Club, London. 2/6 to members.)

Although obviously not a book on astronomy, this volume was received for

review and we therefore shall make at least brief mention of it. As indicated this book is a selection of The Scientific Book Club of England. The reader, cognizant of present-day practice in medicine, will be surprised to learn that methods in the treatment of illnesses a century ago were unbelievably primitive. He will be appalled at the enormous suffering which was endured, and at the same time he will be heartened by the methods of relief developed in the period considered. The author of the volume has presented his material in a clear and convincing and interesting manner, so the attention of the reader is held throughout.

The volume consists of three parts, each divided into several chapters. At the close are found a chronological table of events of medical importance, a short bibliography, and an index. There are 344 pages in all. C.H.G.

The Moon with Naked Eye and Field Glasses, by Calvin J. Joyner. (The Tientsin Press, Ltd., Tientsin, China.)

This book published a few years ago, should be called to the attention of those who are interested in the celestial objects and who have at most a pair of field glasses as supplementary optical equipment. Such persons naturally are attracted to making observations of the moon, the most conspicuous object in the night sky. The book before us furnishes a valuable adjunct to such study. Eleven large scale photographs of the moon at different phases are reproduced. Each of these is accompanied by a chart on which the various features shown in the photograph are delineated and identified. The observer may thus with very little effort recognize by name the particular region he is viewing. In addition the numerous craters, seas, mountains on the moon are described and explained.

Somewhat as a surprise one finds tucked in a pocket attached to the back cover a map, twenty-four inches in diameter, of the moon. Here again many of the prominent features are clearly labeled. Identification is further facilitated by an alphabetical index in the text. Here each feature is named and its location on the map is indicated by letters and numerals along the margins, somewhat as is done in road maps nowadays.

With this volume, a pair of field glasses, and a little perseverance any intelligent person may become quite familiar with the markings on the moon, the most satisfactory celestial object for study by a beginner. C.H.G.

Natural History and the American Mind, by William Martin Smallwood, Chairman of the Department of Zoology in Syracuse University, in Collaboration with Mabel Sarah Coon Smallwood. (Columbia University Press, Morningside Heights, New York. Pages: xv + 445, illus. Price: $4.25.)

This volume is number 8 in the series of Columbia Studies in American culture. It is the story, told for the first time, of the early American naturalists and their influence upon the cultural life of the American people. As such, it tells of the development in America, up to about 1850, of the evolutionary sciences. The end of this story, therefore, comes at that point at which the forerunners of the modern scientific specialists appear.

These authors observe that the growth of every science is accompanied by the appearance of good story-tellers whose vivid imaginations enable them to pass easily over minor inaccuracies and who are not troubled by the sources of their statements. Captain John Smith was such a story-telling naturalist and this work logically begins with the first fabulous reports to the Old World of the natural

phenomena to be seen in this new one.

In between the days of these stories and the appearance in the Nineteenth Century of scientists who realized that observation, classification, and verification must always precede deduction, in between these two periods lay the one described in this book, the one in which natural history blossomed as a cluster of sciences, a grand aggregate of knowledge. This was the time when botany, biology, mineralogy, zoology, and geology, collectively and individually, systematically and casually, attracted the attention of early and enthusiastic contributors to universal knowledge. These persons, or naturalists, played a most important part not only in the growth of science, but also in the development of American culture. These were men who were inclined to fit their new explanations of nature to the current philosophies of their period; in direct opposition to the modern scientist who seems to lay the foundation for the philosophy of the next generation.

As a contribution to the story of American culture this work will bear much examination, not only by students of intellectual history seeking the beginnings of the discrete disciplines or sciences of botany, mineralogy, zoology, geology, and biology, but also by those who are (1) interested in the struggle of these disciplines for pedagogical recognition as independent and important fields, (2) seeking some measure of the effect this intellectual development had upon culture and commonly accepted philosophy, (3) looking for more light upon the strains this movement made upon theological opinion, (4) needing to know the part that lyceums, botanical gardens, museums, and societies played, (5) interested in learning the relationship of the lens, knowledge of optics, and especially of the microscope to this whole development, (6) and finally by those who are interested in publishing and art—for here is the story of the illustrated book and its part, and that of its publisher and illustrator, in this whole subject.

CONTENTS

1. Early Writings on American Natural History
2. Natural History in the Colleges, 1640-1790
3. What Americans Studied in European Universities
4. Some Early Cultural Centers
5. Diffusion of Natural History Culture
6. The Contribution of Publishers, Artists, and Engravers to the Science of Natural History.
7. The Part Played by the Microscope
8. The Philosophy of the Naturalist
9. Amos Eaton and the Academies
10. Early Teaching of Natural History in the Colleges
11. Natural History Struggles for Academic Recognition
12. The Passing of the Naturalist

Bibliography
Index

Teleport (The Teleport Co., Los Angeles, California.)

This is a new word used to describe a new device. The purpose of the device is to show readily and accurately the distance and the difference in time between any two points on the earth's surface. It, therefore, answers the question which frequently arises in connection with news flashes constantly arriving from all parts of the world. Its construction is simple, consisting merely of a flat representation of the spherical earth and a convenient scale for making measurements on it. It contains explicit instructions for making the measurements and for interpreting them. It is a logical adjunct to the telegraph and world-wide broadcasts.

C.H.G.